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Executive Summary

Native cutthroat trout (*Oncorhynchus clarki*) in Colorado have been reduced to <1% of their historic habitat, primarily due to interactions with nonnative salmonids and habitat degradation. The majority of populations now occur in small pieces of habitat in streams or lakes above barriers that prevent invasion by nonnative salmonids. Management has consisted mainly of locating remnant populations and establishing new populations through translocations of genetically pure cutthroat trout into waters that were previously barren of fish or treated with fish toxicants to remove nonnative species. However, empirical evidence suggests that this strategy may not ensure long-term persistence. Our goal is to develop tools for predicting risk of extinction from habitat variables for native cutthroat trout populations isolated in headwater streams. We are currently measuring these habitat features for Rio Grande and greenback cutthroat trout drainage basins that support stable and unstable historic and transplanted populations that are not excluded by nonnative species. To date (May 1998) we have completed field work for 22 streams with translocated populations of cutthroat trout (12 Rio Grande, 10 greenback).

Overall, temperature data for 13 streams measured so far indicate that low summer temperature may be an important critical factor limiting populations of cutthroat trout. Logistic regression models developed for 22 streams surveyed so far also suggest that wider streams with pools containing clean gravel and large physical structures such as large woody debris may be important habitat factors for persistence of cutthroat trout. However, these results are preliminary and may vary when temperature data from 19 more streams and habitat data from 10 more streams are included in the analyses. Future analyses will also incorporate basin-scale habitat variables measured from digital map data with a Geographic Information System for both translocated and historical Rio Grande and greenback cutthroat trout streams to develop the best model for predicting persistence of cutthroat trout.

Native cutthroat trout (*Oncorhynchus clarki*) in Colorado have been reduced to <1% of their historic habitat, primarily due to interactions with nonnative salmonids and habitat degradation. The majority of populations now occur in small segments of habitat in streams or lakes above barriers that prevent invasion by brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), or rainbow trout (*Oncorhynchus mykiss*). Management to date has consisted mainly of locating remnant populations and establishing new populations through translocations of genetically pure cutthroat trout into waters that were previously barren of fish or treated with fish toxicants to remove nonnative species (Stuber et al. 1988).

Empirical evidence suggests that this strategy may not ensure long-term persistence. For example, although Rio Grande cutthroat trout (*O. c. virginalis*) have been transplanted to 24 stream segments in Colorado, only 5 (21%) have produced stable populations whereas 9 are unstable or have died out, presumably due to unknown problems with habitat (10 others were invaded by nonnative species; Harig and Fausch 1996). Similarly, of 21 streams to which greenback cutthroat trout (*O. c. stomias*) were transplanted, only 5 (24%) have produced stable populations, whereas 6 of the 16 that are unstable or have died out are due to unknown habitat problems (8 were invaded by nonnatives, 2 are affected by heavy metals; U.S. Fish and Wildlife Service [USFWS] 1998).

It is clear from these results that managers need better information on two aspects of cutthroat trout ecology; the biotic interactions by nonnatives that cause exclusion of cutthroat trout, and the macrohabitat features that promote long-term persistence of cutthroat trout populations versus those that increase risk of transplant failure. The

purpose of our research is to address the latter problem. Our goal is to develop tools for predicting risk of extinction from habitat variables for native cutthroat trout populations isolated in headwater streams. We are currently measuring these habitat features for drainage basins that support stable and unstable historic and translocated populations that are not excluded by nonnative species, at both map and field scales. To date (May 1998) we have completed field work for 22 streams with translocated populations of cutthroat trout (12 Rio Grande, 10 greenback) and preliminary map-scale analyses for 27 Rio Grande cutthroat trout streams (see Harig and Fausch 1997 for these latter results). The results of nine stream surveys conducted in summer 1998, thermograph data on 1996-97 annual temperature regimes from 13 streams, and preliminary statistical analyses of the field-scale macrohabitat variables from all 22 streams are reported here.

Methods for Reach- and Pool-Scale Habitat Measurements

We identified 32 streams in Colorado and New Mexico that have translocated populations of Rio Grande or greenback cutthroat trout that are not being excluded by nonnative salmonids or influenced by other factors unrelated to habitat (based on data in USFWS 1998, CDOW 1997, Harig and Fausch 1996, and Bill Stumpff, NMDGF, personal communication). Thirteen of these streams were randomly selected for field surveys during 1996, nine were sampled in 1997 (Table 1), and the remaining streams are scheduled for field surveys in 1998.

Field surveys were conducted at reach and pool scales during June - September 1997. The habitat survey was conducted along the entire stream reach from the downstream fish movement barrier upstream to where the active channel was less than 1.0

m wide. Potential barriers to fish movement were characterized by type (e.g., waterfall, cascades, steep gradient, dry channel, manmade structure), width from right to left banks, height between water surfaces, and maximum depth of the pool below the barrier (the last two were measured if applicable). Barrier locations were marked on a 1:24,000 topographic quadrangle. Bank composition at barriers was classified as bedrock, boulders, or other substrate, and riparian vegetation was described as dominant vegetation type and approximate diameter at breast height (DBH).

Reach Attributes

Each stream was stratified into relatively homogeneous reaches less than 2.5 km long based on gradient and valley morphology. Each reach was characterized by the following variables:

length- measured from 7.5 minute topographic quadrangle

gradient- calculated from 7.5 minute topographic quadrangle

stream flow- observed discharge condition (ODFW 1994):

dry-	no water in the channel
puddled-	series of isolated pools connected by surface trickle or subsurface flow
low flow-	surface water flowing across 50-75% of the active channel surface
moderate flow-	surface water flowing across 75-90% of the active channel surface
high flow-	stream flowing completely across active channel surface but not at bankfull
bankfull flow-	stream flowing at the upper level of the active channel bank
flood flow-	stream flowing over banks onto low terraces or floodplains

fast water type- dominant non-pool habitat: riffle, run, or cascade (Hawkins et al. 1993)

riparian vegetation- dominant and subdominant vegetation types and approximate sizes, estimated as diameter at breast height (DBH)

land use- dominant land use: wilderness, grazing, mining, forest products, etc.

valley shape- V or U shaped, presence or absence of hillslopes and terraces

lateral migration- the stream's potential for lateral migration (i.e., constrained or unconstrained)

benthic invertebrates- presence/absence and dominant taxa visually determined from samples of large channel substrate

Temperature

Temperature is measured a minimum of every 24 minutes for at least one year by either an Optic StowAway® or TidbiT® thermograph (Onset Computer Corporation, Pocasset, MA) placed in the deepest pool. Thermographs will be retrieved in summer or fall 1998. Fourteen thermographs recording 1996-97 annual temperature regimes were retrieved from 13 streams surveyed in summer 1996 and one stream surveyed in 1997 (upper Ouzel Creek). New thermographs were placed into 10 of these streams to document annual variability and will also be retrieved during summer or fall 1998.

Data from the fourteen thermographs were summarized as minimum, average, and maximum daily temperatures (°C). Preliminary analyses were based on the sum of average daily temperatures (degree days) for the months of July and August to approximate periods of egg incubation and emergence of cutthroat trout fry. No other analyses were conducted at this time because the dates of thermograph deployment in each stream did not overlap for all months.

Pool Attributes

Field measurements were made at each pool, identified as a channel unit that is at least one channel width long, generally deep and slow-flowing, with a gentle surface water slope (Hawkins et al. 1993). The following variables of fish presence, pool size, substrate, and physical structure were measured at each pool:

fish- number of each species of fish observed through polarized glasses by carefully approaching the pool from downstream

approximate size- estimated size or size class of the fish

pool visibility- pool conditions at time of visual observation: clear (visual observation possible), or occluded (no visual observation because of low light levels or turbid water)

pool type- channel geomorphic units which are formed by interactions among discharge, sediment load, and channel resistance to flow according to Hawkins et al. (1993):

	Characteristic			
Pool Type	Deep Point-Longitudinal Profile	Deep Point-Cross-sectional Profile	Substrate Character	Forming Constraint
SCOUR:				
convergence	mid	mid	sorted, fine at head	convergence of streams
mid-channel	mid	mid	uniform, resistant	constriction at head
lateral	up or mid	side	sorted, resistant	deflector at head
plunge	up	variable	sorted	obstruction at head
trench	uniform	uniform	uniform, resistant	bilateral resistance
DAMMED:				
debris	tail	variable	sorted, fine	debris
beaver	tail	variable	uniform, fine	beaver dam
boulder	irregular	irregular	variable	large substrate

tail crest depth- minimum tail crest depth measured at the downstream point of hydraulic control that forms the pool (Lisle 1987)

maximum depth- maximum depth measured after searching the pool bottom for the deepest point

residual depth- residual depth calculated as the maximum depth minus the tail crest depth (Lisle 1987)

DS width- measured as bankfull width (water surface level with the floodplain; Dunne and Leopold 1978) at the downstream end of pool

MS width- measured as bankfull width at center of pool

US width- measured as bankfull width at the upstream beginning of pool

average width- an average of the three measured pool widths

length- measured along the stream centerline (Fausch and Northcote 1992)

area- pool area calculated as length multiplied by average width

undercut bank- measured length of banks that were at least 10 cm undercut, no more than 15 cm above the water surface, and had a minimum water depth of 10 cm (adapted from Fausch and Northcote 1992)

LWD- counted the number of pieces of large woody debris (LWD) that are at least 15 cm in diameter for 3 m of length (adapted from Richmond and Fausch 1995), and at least partially in or suspended over the bankfull channel including pieces forming pools

gravel- estimated the percent of pool tail area (downstream ¼ of pool length) that was covered by gravel 2-63 mm in diameter, as an index of substrate available for spawning

embeddedness- classified the gravel as clean (C), partially embedded (P), or 100% embedded in fine sediments (silt and sand <2mm in diameter; S)

boulders- counted the number of boulders that were >50 cm in diameter in all dimensions and within the bankfull channel, including those that formed the stream bank if they protruded into the pool

shade L- canopy cover on the left bank (facing downstream) measured with a clinometer as the angle from the channel horizontal to the sun horizon (Platts et al. 1983)

shade R- canopy cover on the right bank (facing downstream) measured with a clinometer as the angle from the channel horizontal to the sun horizon (Platts et al. 1983)

sun arc- the angle made by the arc of the sun as it intercepts the mid-point of the channel, calculated as 180 degrees minus the sum of shade L and shade R (Platts et al. 1983)

Model of Translocation Success

Preliminary analyses of field data were conducted to identify potential critical habitat factors that allow the establishment of naturally reproducing populations from translocation of cutthroat trout. The analyses compared characteristics of streams where cutthroat trout have been successfully translocated (i.e., have established naturally reproducing populations) versus those where they have not. We assumed that streams with populations of cutthroat trout have good habitat, while streams that failed to support a population have poor habitat.

Statistical analyses of field habitat data utilized one-way ANOVA for univariate tests (S-Plus; MathSoft Inc. 1997) and binary logistic regression for multivariate tests (SAS Institute Inc. 1996). The best logistic regression model of field habitat was selected based on minimizing values of Akaike's Information Criterion (AIC; Hosmer and Lemeshow 1989). However, results from these analyses are preliminary and may change upon inclusion of the remaining cutthroat trout streams to be surveyed in 1998.

Results

Barriers to Fish Movement

Each stream survey began at a barrier to fish movement, which ranged from natural barriers such as waterfalls, cascades, steep gradient reaches, and dry stream channels to anthropogenic barriers such as rock gabions (Table 1; Figures 1-9). There are

natural barriers on all streams except for Middle and West Forks of San Francisco Creek, which have rock gabions. It is unlikely that these rock gabions would prevent the upstream movement of nonnative salmonids if they were present in the main stem of San Francisco Creek because they are only 0.4 and 0.8 m in height. However, an irrigation diversion at the downstream end of the main stem of San Francisco Creek may be an effective barrier for preventing invasion by nonnative salmonids into the Middle and West forks. It is also uncertain if the 1.6-m high cascade barrier on the upper North Fork Big Thompson River will prevent invasion by brook trout if they move upstream from below Lost Lake. Fortunately, the cascade is in a narrow canyon preventing the formation of side channels at higher flows that could provide an easier route for the brook trout to surmount. All potential barriers were inspected to assess the potential for such alternate routes at higher flows.

Three streams have steep cascades or falls in their middle reaches which may potentially divide them into multiple habitat units. The upper reaches of Medano Creek have six potential barriers to fish movement including four bedrock waterfalls or cascades with minimum heights of 2.3 m (Figure 3). Upper Ouzel Creek has one steep cascade section (h = 5.0 m; Figure 6) which may effectively split the stream into two habitat units. Roaring River has three barriers to fish movement including two steep bedrock slides (gradients = 24 and 25%; Figure 7). Greenhorn Creek and North Fork Big Thompson River also have cascades or waterfalls in their middle reaches (h = 0.8-1.0; Figures 1 and 5), but they may not prevent the upstream movement of trout.

The upper terminus of seven surveys was identified where the active channel was less than 1.0-m wide, including three surveys ending at headwater lakes (Medano Creek,

Roaring River, and upper North Fork Big Thompson River). The survey on Middle Fork San Francisco Creek ended at a bankfull width of approximately 1.3 m because no cutthroat trout had been seen for ca. 5.0 km and pool density was greatly reduced. The survey on upper Ouzel Creek ended at a steep gradient reach (22%; length = 0.6 km) below Bluebird Lake thought to be a barrier to fish movement.

Characteristics of Stream Reaches

Stream reaches for each habitat survey are defined in Figures 1-9 and described in Tables 2 and 3. Impacts from recent and past grazing such as short grass, damaged riparian vegetation, and trampled stream banks were evident on Middle and West Forks of San Francisco Creek and Williams Gulch. Cattle were present at Middle and West Forks of San Francisco Creek but not at Williams Gulch during our surveys. Recent or past beaver activity was also recorded at Medano Creek and Middle and West Forks of San Francisco Creek. Beaver ponds often created some of the largest pools with the greatest amount of large woody debris. The U.S. Forest Service had enhanced pools in Williams Gulch by adding log drop structures.

Average stream gradients for all streams calculated from the topographic quadrangles ranged from 4% on North Fork Big Thompson River to 11% on Greenhorn Creek. Shorter low-gradient reaches equal to or less than 6% were present on all streams except for Greenhorn Creek. Gradient calculated from maps is likely to be higher than actual gradients due to greater stream sinuosity (and therefore greater channel length) on the ground than can be shown on maps.

Model of Translocation Success

Streams were classified based on their cutthroat trout population status for comparison of selected habitat variables and development of a preliminary model of translocation success. Population status was assigned based on an index of relative trout abundance, presence of natural reproduction, and previous designation by the Colorado Division of Wildlife (CDOW; USFWS 1998, CDOW 1997, Harig and Fausch 1996). The index of relative abundance was determined as the number of cutthroat trout observed in all pools divided by the stream length (Table 1, Figure 10). These values were then compared to the CDOW electrofishing data and previous status designation for a final classification (Table 1). The visual estimates of cutthroat trout abundance do not consistently over- or underestimate the density of trout compared to the CDOW estimates of standing stock based on electrofishing (Figure 11). The differences in trout abundance for individual streams may be attributed to differences in the length of samples. The visual sample includes the entire stream whereas estimates based on electrofishing utilize shorter reaches that are not likely to be representative of all habitat.

A status rating of "absent" was assigned to West Fork San Francisco Creek because it had no cutthroat trout. A status rating of "low" was assigned to Little Ute Creek, Middle Fork San Francisco Creek, and Roaring River because there was evidence of natural reproduction (i.e., multiple size classes, young-of-the-year) but numbers of cutthroat trout observed were low (≤10 fish/km). A rating of "common" was assigned to Upper Ouzel Creek, Greenhorn Creek, Upper North Fork Big Thompson River, Medano Creek, and Williams Gulch because there was evidence of reproduction over multiple years and numbers of trout observed were relatively high (≥20 fish/km). The 1996

streams retained their classification as outlined in the 1997 annual report except for Cottonwood Creek, which was reassigned as "absent" instead of "low" because natural reproduction has not been documented. All trout present in the stream are presumably the result of stocking efforts only (USFWS 1998). These classifications seem appropriate for analyses because they incorporate CDOW data, and most streams were small, shallow, and relatively clear allowing adequate observation of trout.

Preliminary statistical analyses of the field habitat data compared streams with populations of cutthroat trout (combining both low and common status categories) to streams that failed to support a stable population (absent status category). Analyses which attempt to differentiate between all three status categories will be conducted in 1999 after the remaining streams have been surveyed and thermographs have been retrieved.

A. Model based on Temperature

Thermographs from 14 streams recording 1996-97 annual temperature regimes were retrieved from 13 streams surveyed in summer 1996 and one stream surveyed in 1997. Minimum and maximum daily temperatures from each stream are presented in Figures 12-25. Winter temperatures were similar for all streams and were usually between 0.2 – 2.0 °C. No streams had significant periods of freezing temperatures (<0 °C) in the pool habitats containing the thermographs suggesting that overwintering refuges are available in these streams.

The sum of mean daily temperatures (Celsius degree days; DD) for July and August, months which approximate periods of egg incubation and emergence of cutthroat trout fry, ranged from 284 DD in Hourglass Creek to 605 DD in East Middle Creek

(Figure 26). Data for Cottonwood Creek were only available up to 7/23/97, so could not be included in the analyses at this time. Streams without cutthroat trout (absent status) had significantly colder temperatures with DD less than 455 versus streams with cutthroat trout (low and common status), which had DD greater than 472 ($p=0.0004$ by ANOVA). This strongly suggests that low summer temperatures may be a limiting habitat factor determining which streams can support naturally reproducing cutthroat trout populations.

B. Model based on Field Habitat

Selected habitat variables from nine 1997 and thirteen 1996 stream surveys were summarized (Table 4) for preliminary logistic regression analyses of differences in habitat between the population status categories. It is important to note that temperature could not be included in these analyses because we do not have data from all 22 streams at this time. Thermographs deployed in 1997 will be retrieved in 1998. Given the potential importance of summer temperatures as a limiting factor in establishing a naturally reproducing cutthroat trout population, this habitat model should only be considered preliminary and may change upon inclusion of complete temperature data.

The habitat variables suspected to be most important for persistence of cutthroat trout based on their ecology include measures of habitat size, structural complexity, and spawning habitat. Habitat size, including availability of overwintering refuges, was modeled using length of the stream surveyed, average bankfull width of pools, density of all pools, and density of large, deep pools. Large, deep pools were defined as pools with a minimum area of 11.4 m^2 and a minimum residual depth of 30 cm. Structural complexity was modeled using density of pools with at least one piece of large woody debris, density

of pools with at least one boulder, and density of pools with a minimum of 0.2 m of undercut bank. It was assumed that trout could utilize even minimum amounts of structure. Spawning habitat was modeled as the density of pools with at least 25 % of the pool tail covered by clean gravel. A relatively low percentage of clean gravel was chosen for analyses because spawning gravel was also present in the riffle habitats of many streams. Elevation at the lower terminus of the trout distribution (or lower terminus of the survey if no trout were present) and average canopy cover were included as a proxy for stream temperature.

The best model based on habitat data from 22 streams (minimizing AIC values) included average bankfull width of pools, density of pools with at least one piece of large woody debris, and density of pools with clean gravel as factors predicting the presence or absence of cutthroat trout ($p = 0.007$ by logistic regression). Bankfull width and density of pools with clean gravel were positively associated with presence of cutthroat trout ($p = 0.02$ and 0.12 by one-way ANOVA, respectively; Figures 27 & 28). Density of pools with large woody debris was not positively associated with presence of cutthroat trout when tested alone ($p = 0.70$ by one-way ANOVA, but assumptions of normality and equal error variances are violated) due to an outlier (Figure 29). Hourglass Creek had the greatest density of pools with large woody debris yet does not contain cutthroat trout. Most of the other absence streams have lower densities of pools with large woody debris than streams with cutthroat trout ($p=0.09$ by ANOVA excluding Hourglass Creek, assumptions of normality and equal error variances are met). Therefore, the importance of large woody debris may be more accurately portrayed in future analyses that include temperature data

because Hourglass Creek had the lowest cumulative degree days for July-August of any of the 13 streams measured so far.

Discussion

This work is part of ongoing research to identify the characteristics of streams where native cutthroat trout have persisted versus those where they have not. This research is expected to identify critical habitat factors that allow long-term persistence of cutthroat trout populations isolated in headwater reaches. The results will allow managers and biologists to identify populations at greatest risk from extirpation and propose habitat variables to measure for evaluation of potential introduction sites. Overall, patterns emerging from the reach-scale field data suggest that low summer temperature may be a critical factor limiting populations of cutthroat trout. The colder summer temperatures (July and August) in absence streams may not adequately support the successful incubation and emergence of fry. Eggs undergoing prolonged incubation at low water temperatures often result in low embryo survival and increased time to hatching (Hubert et al. 1994), particularly for cutthroat trout (Stonecypher et al. 1994). This is especially important for waters which may not reach minimum spawning temperatures until mid-July because embryos that survive and hatch late may not have enough time to grow large enough to survive the winter (Hunt 1969, Cunjak and Power 1987).

Additional evidence from logistic regression models based on habitat variables from all 22 streams measured so far suggests that stream size, presence of large physical structures particularly large woody debris, and the presence of clean spawning gravel may also be important factors in determining the persistence of cutthroat trout. However, a

full model incorporating all habitat variables including temperature can not be developed until the remaining thermographs are retrieved. Therefore, these results should only be considered preliminary and may change in future analyses.

Ongoing Work

During the summer 1998 field season we plan to survey the remaining 10 streams where Rio Grande and greenback cutthroat trout have been translocated and deploy thermographs. We also plan to measure basin-scale habitat variables with a Geographic Information System for the remaining Rio Grande and greenback cutthroat trout streams (27 were measured in 1996-97; see Harig and Fausch 1997), including both translocated and historical populations not displaced by nonnative salmonids. Future analyses will incorporate field habitat data, basin-scale map data, and a combination of both to develop the best model for predicting persistence of cutthroat trout.

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Table 1. Population status and barrier description of 1997 cutthroat trout field streams.

Stream	Fish Index (no./km)	Population status	CDOW designation	Barrier	Barrier location	Barrier description
1. West Fork San Francisco Creek	0.0	absent	unstable	rock gabion	above confluence with San Francisco Creek, MF	height above water = 0.4 m easily surmountable by trout
2. Little Ute Creek	3.2	low	potential	series of waterfalls	North of Burro Park	gradient = 15% reach length = 1.0 km height of largest falls = 3.0 m
3. Middle Fork San Francisco Creek	7.0	low	potential	rock gabion with cement top cap	above confluence with San Francisco Creek, WF	height above water = 0.8 m easily surmountable by trout
4. Roaring River	8.0	low	stable	Horseshoe Falls	above confluence with Fall River	gradient = 49% reach length = 0.2 km
5. Ouzel Creek, Upper	21.0	common	potential	steep cascades	~0.5 km above Ouzel Lake	height of largest falls ~ 5.0 m
6. North Fork Big Thompson R., Upper	28.0	common	stable	small waterfall	~0.8 km above stream fork leading to Lake Louise	height above water = 1.6 m
7. Greenhorn Creek	32.0	common	potential	series of waterfalls	below Camp Crockett Trail crossing	height of largest falls = 2.1 m
8. Medano Creek	33.0	common	stable	dry stream channel	below Great Sand Dunes National Monument Visitor's Center	unknown length of dry stream channel
9. Williams Gulch	58.0	common	stable	steep cascades	above confluence with Cache la Poudre River	gradient = 43% reach length = 0.9 km

Table 2. Reach characteristics in Rio Grande cutthroat trout steams measured during field surveys, June - September 1997.

Reach	Length (km)	Gradient (%)	Pools (no.)	Pool density (no./km)	RGNs in pools (no.)	RGN density (no./km)	Riparian vegetation (D=dominant; S=subdominant) (taxon, cm DBH)	Valley morphology	Fast water type	Comments
Little Ute Creek (7/9/97 & 7/22/97)										
1	1.3	6	6	4.6	0	0.0	D: spruce 10-30 S: forbes	U with terrace	riffles	survey began above a series of falls and steep cascades North of Burro Park (steepest falls h = 5.0m; gradient = 15%)
2	0.9	7	33	36.7	7	7.8	D: blue spruce 10-30 S: forbes	U with terrace	riffles	survey ended at headwater falls
All	2.2	7	39	17.7	7	3.2				
Medano Creek (9/3/97 - 9/17/97)										
1	2.2	1	18	8.2	1	0.4	D: alder and willow	V	riffles and runs	survey began at first pool in Great Sand Dunes National Monument
2	1.2	2	38	31.7	46	38.3	D: alder S: cottonwood 10-30	V	riffles and runs	
3	1.0	3	44	44.0	25	25.0	D: alder and willow S: cottonwood 20-35 S: fir 25-40	V	riffles	gage station monitors discharge and water quality two foot bridges cross stream
4	2.2	3	87	39.5	209	95.0	D: alder and willow S: cottonwood 15-30 S: aspen 15-30	U with terrace	riffles	many beaver ponds

Table 2. Continued.

Reach	Length (km)	Gradient (%)	Pools (no.)	Pool density (no./km)	RGNs in pools (no.)	RGN density (no./km)	Riparian vegetation (D=dominant; S=subdominant) (taxon, cm DBH)	Valley morphology	Fast water type	Comments
5	0.9	4	60	66.7	96	106.7	D: alder and willow S: cottonwood 5-25	U with terrace	riffles	
6	0.8	4	35	43.8	59	73.8	D: alder S: cottonwood 5-25	U with terrace	riffles	large old beaver complex
7	1.1	5	40	36.4	20	18.2	D: aspen 10-30 S: alder	U with terrace	riffles and low gradient cascades	short stream section is constrained by steep bedrock cliffs along left bank
8	1.4	3	58	41.4	188	134.3	D: aspen 5-30 S: willow	U with terrace	low gradient riffles	many beaver ponds
9	1.8	3	41	22.8	25	13.9	D: alder and willow S: aspen 10-25	U with terrace	riffles and runs	eroding banks
10	2.0	8	47	23.5	34	17.0	D: spruce 15-30 D: willow S: aspen 10-30 S: alder	U with terrace	riffles	includes a small section of Medano Creek, Hudson branch below ditch diversion
11	0.8	2	35	43.8	3	3.8	D: willow S: fir 5-20	V	cascades	small waterfall (h = 1.2m)
12	0.9	7	19	21.1	3	3.3	D: spruce 5-20 S: aspen 10-30	V with terrace	riffles	

Table 2. Continued.

Reach	Length (km)	Gradient (%)	Pools (no.)	Pool density (no./km)	RGNs in pools (no.)	RGN density (no./km)	Riparian vegetation (D=dominant; S=subdominant) (taxon, cm DBH)	Valley morphology	Fast water type	Comments
13	0.8	10	30	37.5	0	0.0	D: fir 25-40 S: forbes	V with terrace	cascades	two steep bedrock slides covered with moss (h = 6.0m)
14	0.9	13	60	14.4	0	0.0	D: forbes S: fir 25-40	V	cascades	small waterfall (h = 1.2m) bedrock slide (h = 2.3m)
15	1.2	16	41	34.2	1	0.8	D: forbes S: fir 25-50	V	cascades	bedrock cascades (h = 2.5m) survey ended at large beaver complex and Medano Lake in the headwaters
All	19.2	5	653	34.0	710	37.0				
Middle Fork San Francisco Creek (6/30/97 - 7/1/97)										
1	2.0	6	28	14.0	42	21.0	D: alder, aspen <10 S: spruce 10-30	V wide valley	riffles	survey began above rock gabion (h = 0.4m) many large beaver ponds
2	1.9	8	20	10.5	0	0.0	D: spruce 20-40 S: willow <10 S: aspen 10-20	V	riffles	
3	0.7	11	18	25.7	0	0.0	D: spruce 10-50 S: aspen 10-30	V	riffles	evidence of logging on end moraine
4	1.7	11	27	15.9	0	0.0	D: spruce 20-40	U glaciated	riffles	survey ended at bankfull width ca. 1.3 m
All	6.3	9	93	14.8	42	6.7				

Table 2. Concluded.

Reach	Length (km)	Gradient (%)	Pools (no.)	Pool density (no./km)	RGNs in pools (no.)	RGN density (no./km)	Riparian vegetation (D=dominant; S=subdominant) (taxon, cm DBH)	Valley morphology	Fast water type	Comments
West Fork San Francisco Creek (6/24/97 - 6/25/97)										
1	0.4	6	29	72.5	0	0.0	D: alder S: aspen 25-30	U with terrace	riffles	survey began above rock gabion (h = 0.4m)
2	1.2	8	6	5.0	0	0.0	D: Douglas fir 25-30 S: aspen 25-30	V	steep riffles	many split channels
3	0.7	8	24	34.3	0	0.0	D: willow S: spruce 25-30	V	steep riffles	many split channels
4	1.1	9	8	7.3	0	0.0	D: spruce 30-40 S: aspen 25-30	V	steep riffles	many split channels
5	1.2	10	0	0.0	0	0.0	D: spruce 30-40 S: aspen 25-30	V	steep riffles	survey ended where channel flowed underground
All	4.6	9	67	14.6	0	0.0				

Table 3. Reach characteristics in greenback cutthroat trout steams measured during field surveys, July - August 1997.

Reach	Length (km)	Gradient (%)	Pools (no.)	Pool density (no./km)	RGNs in pools (no.)	RGN density (no./km)	Riparian vegetation (D=dominant; S=subdominant) (taxon, cm DBH)	Valley morphology	Fast water type	Comments
Greenhorn Creek (7/22/97 - 7/23/97)										
1	0.3	7	18	60.0	11	36.7	D: spruce 20-50	V	riffles	survey began at series of falls five waterfalls (h = 0.9-2.1m)
2	0.8	11	46	57.5	48	60.0	D: spruce 20-50	V	riffles	three small waterfalls (h = 1.0-1.3m) slight grazing impacts
3	0.4	9	16	40.0	31	77.5	D: spruce 20-50	V	riffles	slight grazing impacts
4	1.6	11	55	34.4	15	9.4	D: spruce 20-50 S: willow	V	riffles	two steep cascade sections small waterfall (h = 1.0m) slight grazing impacts survey ended at bankfull width < 1.0 m
5 tributary	0.3	16	16	53.3	4	13.3	D: willow	V	riffles	moderate grazing impacts survey ended at a small water fall (h = 1.5m)
All	3.4	11	151	44.4	109	32.0				

Table 3. Continued.

Reach	Length (km)	Gradient (%)	Pools (no.)	Pool density (no./km)	RGNs in pools (no.)	RGN density (no./km)	Riparian vegetation (D=dominant; S=subdominant) (taxon, cm DBH)	Valley morphology	Fast water type	Comments
North Fork Big Thompson River below Lake Louise (7/30/97)										
1	1.0	6	17	17.0	11	11.0	D: spruce 10-30 S: forbes	V	cascades	survey began at cascades (h = 1.6m) above stream split
2	0.5	2	17	34.0	35	70.0	D: willow S: forbes	U with terrace	runs and cascades	steep cascades (h = 0.8-1.8m) at lower end of reach sandy substrate ending in two large, shallow ponds
3	0.3	3	3	10.0	5	16.7	D: willow S: forbes	U with terrace	runs and cascades	rocky substrate survey ended just below Lake Louise
All	1.8	4	37	20.6	51	28.3				
Ouzel Creek above Ouzel Lake (8/11/97)										
1	0.6	10	18	30.0	14	23.3	D: spruce 5-30 S: grasses	V with terrace	cascades	survey began at steep cascades (h ~ 5.0m) above Ouzel Lake
2	0.4	6	6	15.0	7	17.5	D: forbes S: spruce 5-20	U with terrace	steep riffles	steep cascades (h ~ 5.0m) at lower end of reach survey ended at steep gradient reach (22%) below Bluebird Lake
All	1.0	8	24	24.0	21	21.0				

Table 3. Continued.

Reach	Length (km)	Gradient (%)	Pools (no.)	Pool density (no./km)	RGNs in pools (no.)	RGN density (no./km)	Riparian vegetation (D=dominant; S=subdominant) (taxon, cm DBH)	Valley morphology	Fast water type	Comments
Roaring River (8/4/97 - 8/6/97)										
0	1.9	7	0	0.0	0	0.0	D: sparse willow S: sparse forbes	U	cascades	survey began above Horseshoe Falls (gradient = 49%; length = 0.2 km)
1	2.2	6[a]	38	17.3	24	10.9	D: sparse willow S: sparse forbes	U	riffles and cascades	first pool at confluence with Ypsilon Creek steep bedrock slide barrier at upper end (gradient = 25%)
2	0.8	10[a]	11	13.8	14	17.5	D: sparse willow S: sparse forbes	U	riffles and cascades	steep bedrock slide barrier at upper end (gradient = 24%)
3	1.4	6[a]	24	17.1	18	12.8	D: forbes	V	cascades	steep cascades at upper end (gradient = 11%)
4	0.6	3	8	13.3	3	5.0	D: sparse forbes	V	cascades	survey ended at Lawn Lake
All	6.9	8	81	11.7	59	8.6				

a = Gradient calculation for the reach does not include the steep waterfalls presumed to be a barrier to fish movement.

Table 3. Concluded.

Reach	Length (km)	Gradient (%)	Pools (no.)	Pool density (no./km)	RGNs in pools (no.)	RGN density (no./km)	Riparian vegetation (D=dominant; S=subdominant) (taxon, cm DBH)	Valley morphology	Fast water type	Comments
Williams Gulch (7/25/97 & 8/7/97)										
1	1.0	8	40	40.0	54	54.0	D: aspen 5-10 S: aspen 20-30 S: spruce 20-30	V with terrace	cascades	survey began above steep cascade barrier (gradient = 43%; length = 0.9 km)
2	0.7	9	33	47.1	15	21.4	D: fir >30 S: aspen 10-30	V with terrace	cascades	
3	0.5	6	27	54.0	22	44.0	D: fir 5-20 S: spruce 20-30	V with terrace	cascades	
4	0.4	3	39	97.5	42	105.0	D: grasses S: forbes	U	riffles	first meadow reach
5	0.7	4	33	47.1	21	30.0	D: fir 10-20 S: spruce 20-30	V with terrace	riffles	four USFS log-drop pools
6	0.8	3	1	1.2	many[b]	~105.0[b]	D: grasses	U with terrace	none	second meadow reach entire reach is one long pool survey ended at source spring
All	4.1	6	173	42.2	>>154	~58.0				

b = There were too many cutthroat trout to keep an accurate count, but the density of trout in reach 4, a meadow reach with similar habitat, was considered a fair minimum estimate.

Table 4. Selected stream habitat variables quantified from field surveys of Rio Grande and greenback cutthroat trout streams, summers 1996 and 1997. Deep, large pools have a minimum residual depth of 30 cm and minimum pool area of 11.4 m^2. Pools with large woody debris (LWD), boulders, and undercut bank have at least one log, boulder, or 0.2 m of undercut bank, respectively.

Stream	Length surveyed (km)	Lower elevation (m)	Mean bankfull pool width (m)	Mean residual depth (cm)	Pool Density					
					all pools (pools/km)	deep, large pools (pools/km)	with LWD (pools/km)	with boulders (pools/km)	w/ undercut bank (pools/km)	with ≥25% clean gravel (pools/km)
Benito Creek	2.6	3231	1.8	26	19.6	0.4	2.3	10.0	1.2	0.0
Hourglass Creek	2.8	2865	3.8	36	55.0	26.4	52.5	40.0	21.8	25.7
San Francisco Creek, WF	4.6	2890	2.8	23	14.6	0.4	9.1	7.2	5.6	0.2
Unknown Creek	3.7	3133	1.0	16	12.2	0.0	1.4	4.3	3.5	1.6
Little Medano Creek	3.1	2560	2.1	36	15.2	0.0	10.6	12.3	12.2	3.2
Cottonwood Creek	5.3	2828	2.6	37	36.2	4.5	6.0	34.0	20.9	13.4
Rhodes Gulch	3.3	2938	2.3	21	24.8	0.6	12.4	11.2	8.8	10.6
Little Ute Creek	2.2	3240	4.5	33	17.7	9.1	5.0	13.2	6.4	9.1
San Francisco Creek, MF	6.3	2900	3.1	29	14.8	1.9	3.3	9.8	7.1	5.2
Rio de los Pinos	3.1	3292	3.2	26	38.1	3.2	2.6	37.1	8.7	27.1
Medano Creek, Hudson	1.1	2981	2.3	23	18.2	0.0	6.4	10.0	10.0	5.4
May Creek	4.7	2731	3.3	31	69.1	20.4	28.9	63.2	27.6	41.9
Roaring River	6.9	2910	4.9	38	11.7	7.7	4.5	11.3	2.6	7.4
Ouzel Creek, Upper	1.0	3130	4.1	35	20.0	11.0	13.0	24.0	11	7.0
Rough Canyon	1.6	2728	3.2	26	36.9	3.8	28.1	21.3	18.8	18.1
Greenhorn Creek	3.4	3100	2.9	44	44.4	18.5	10.3	43.2	23.5	7.9
Fern Creek	2.4	2682	4.5	37	35.0	20.8	30.8	29.6	15.8	19.6
Cony Creek, Lower	3.6	2865	5.5	38	57.8	34.7	47.2	47.8	26.4	30.8
NF Big Thompson, Upper	1.8	3280	3.1	32	20.6	6.1	5.5	20.6	13.3	0.0
East Middle Creek	3.5	2950	3.2	26	46.3	6.3	19.7	30.0	18.6	28.6
Medano Creek	19.2	2520	3.9	36	34.0	16.1	23.8	16.1	17.5	16.8
Williams Gulch	4.1	2770	2.3	33	39.1	10.7	20.7	36.1	31.9	20.7

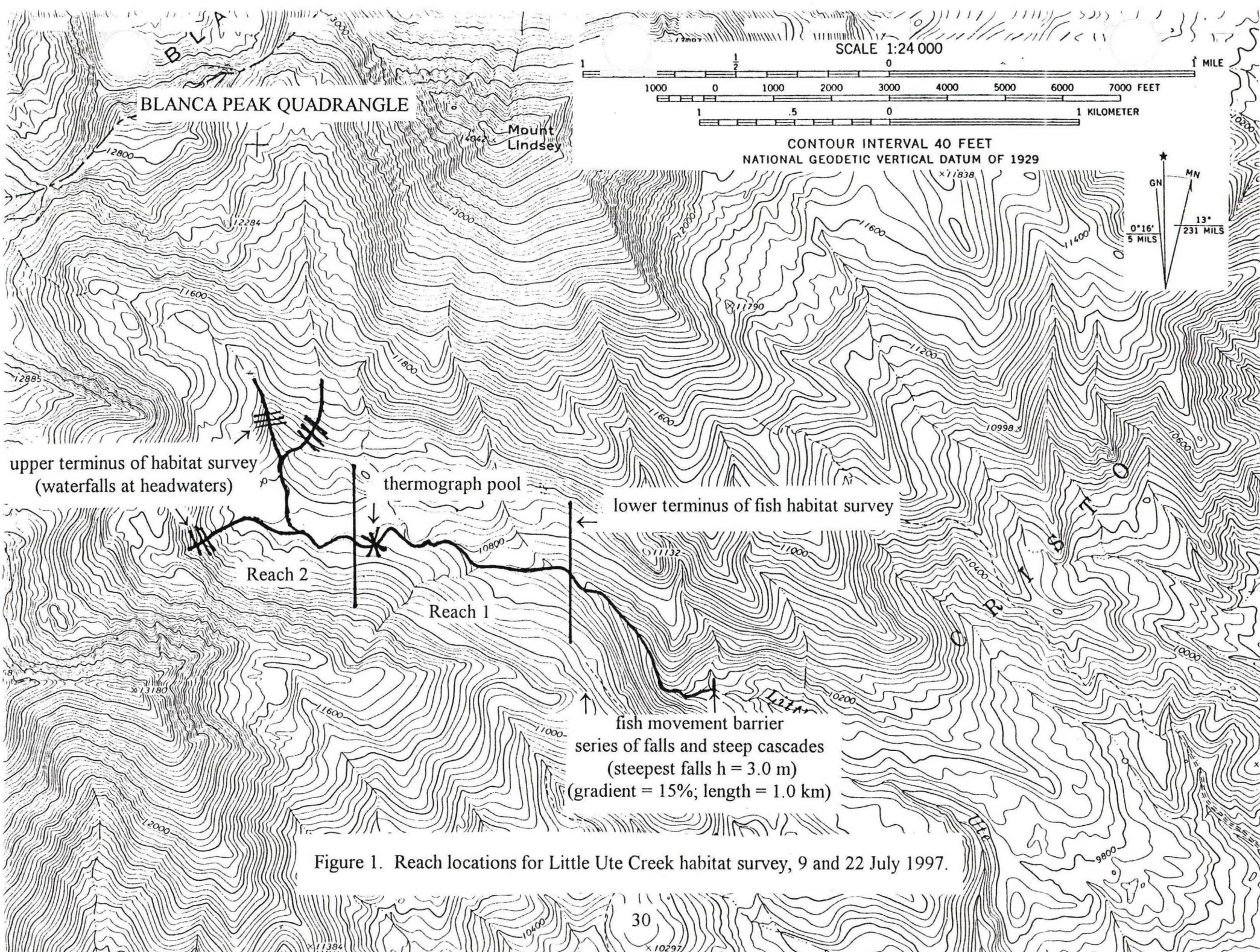

Figure 1. Reach locations for Little Ute Creek habitat survey, 9 and 22 July 1997.

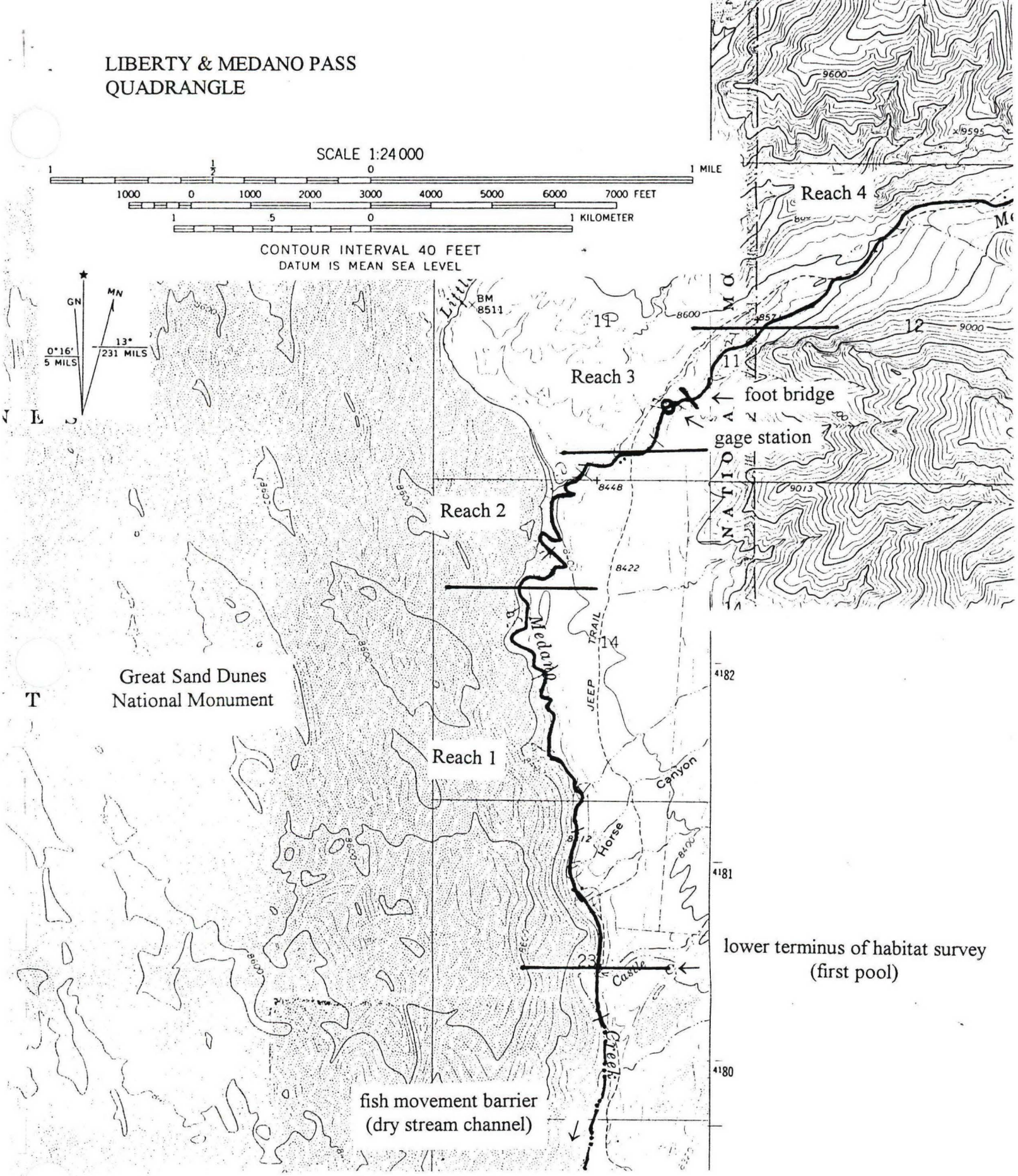

Figure 2. Reach locations for Medano Creek habitat survey, 3-17 September 1997.
(Continued on next page.)

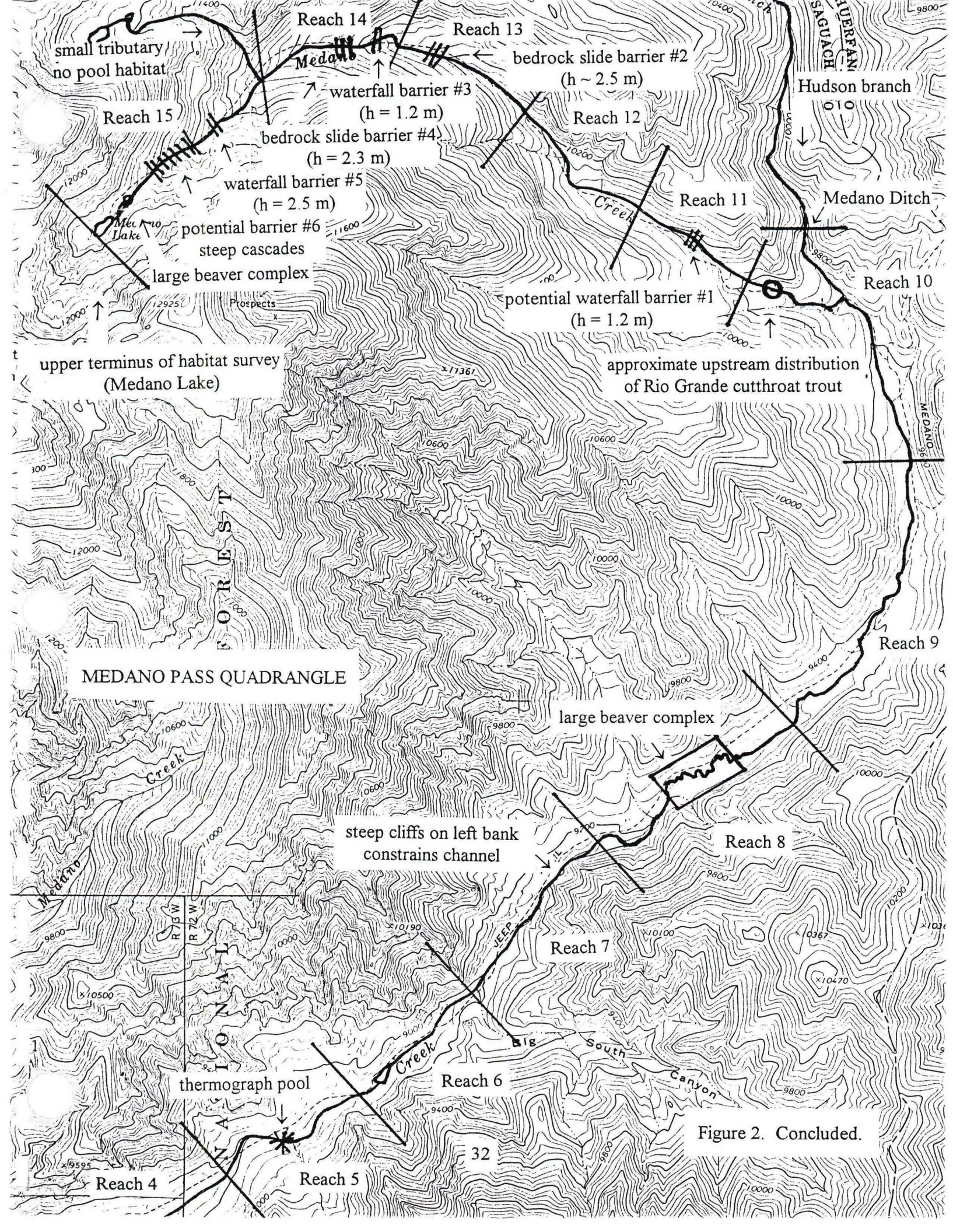

Figure 2. Concluded.

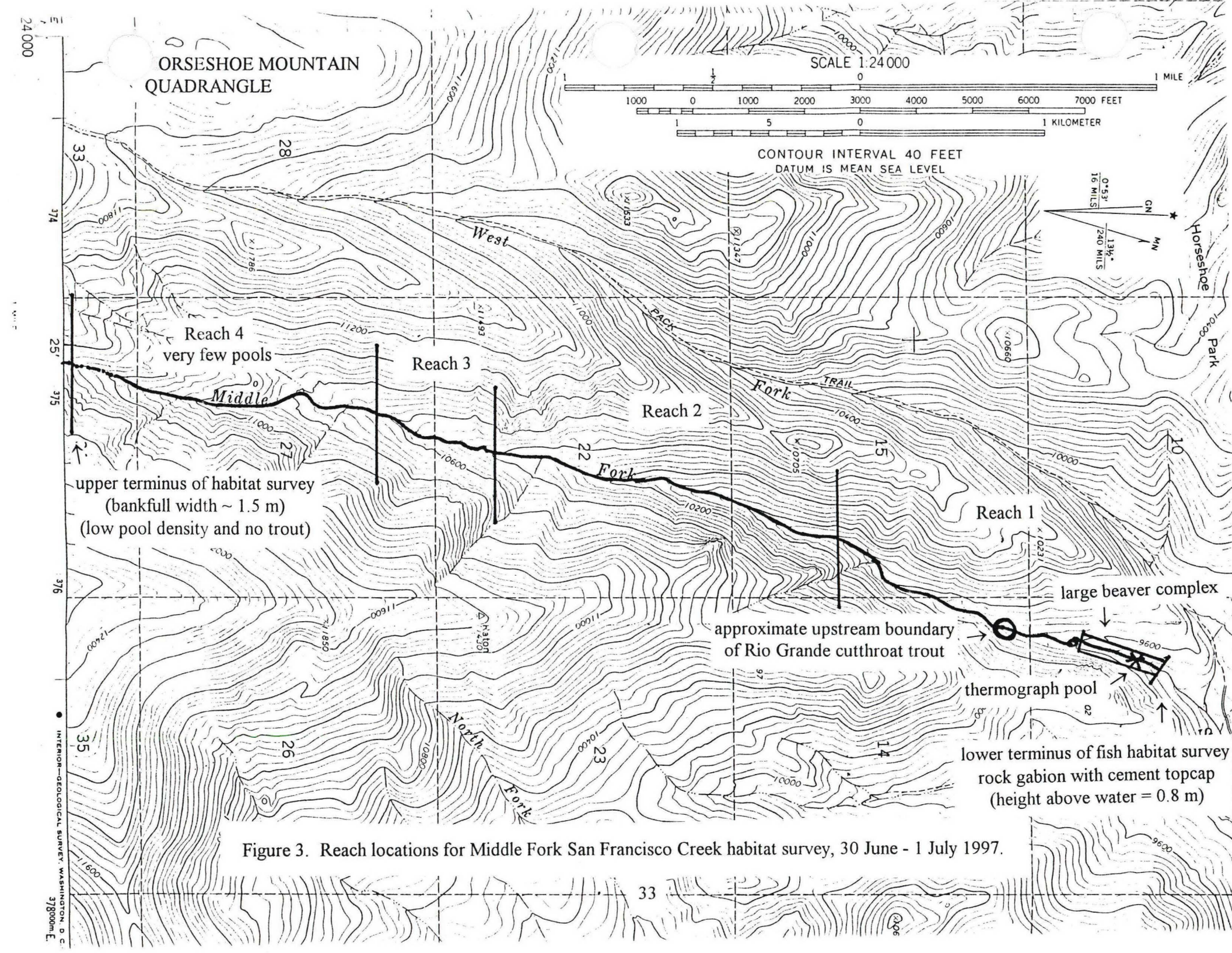

Figure 3. Reach locations for Middle Fork San Francisco Creek habitat survey, 30 June - 1 July 1997.

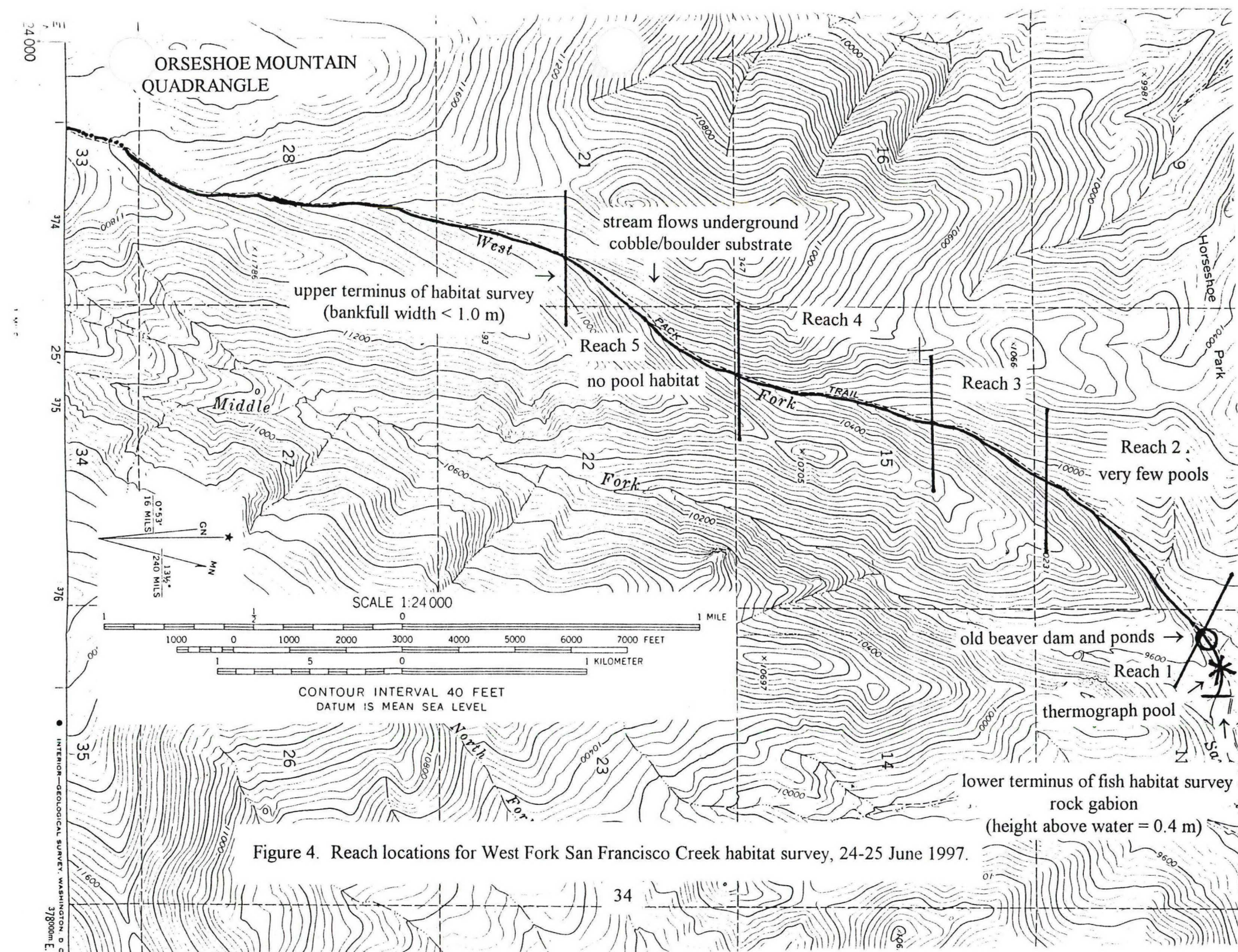

Figure 4. Reach locations for West Fork San Francisco Creek habitat survey, 24-25 June 1997.

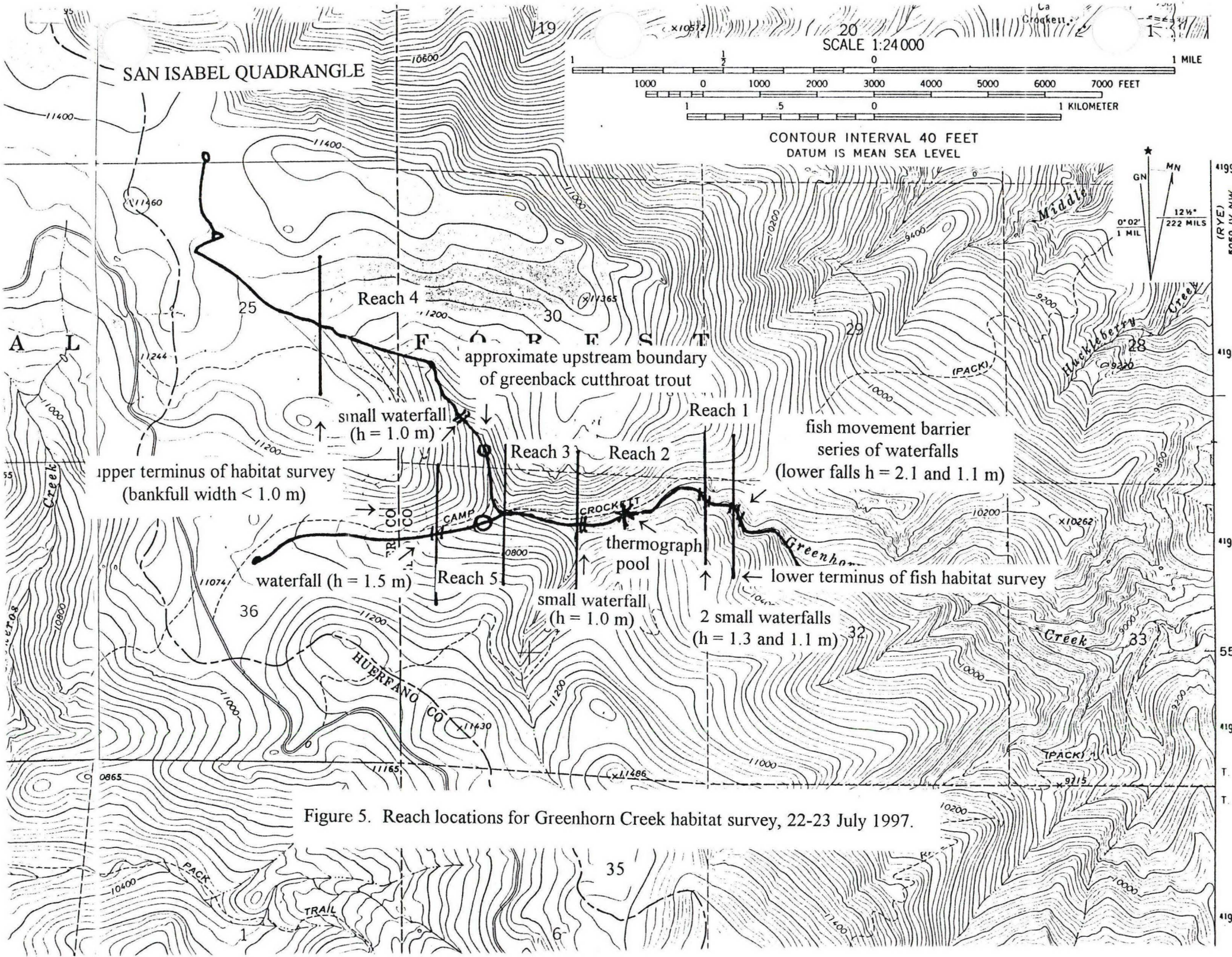

Figure 5. Reach locations for Greenhorn Creek habitat survey, 22-23 July 1997.

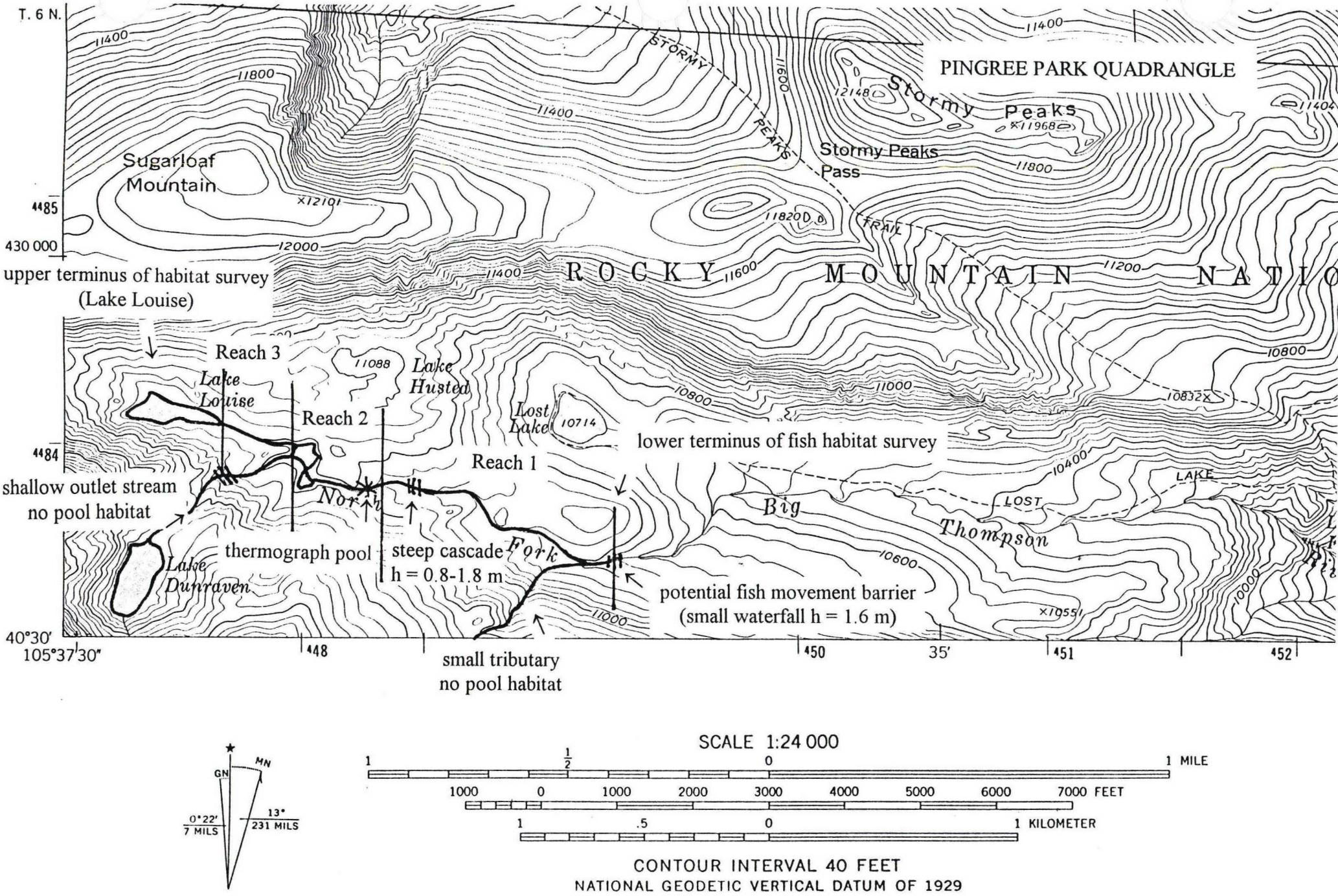

Figure 6. Reach locations for upper North Fork Big Thompson River habitat survey, 30 July 1997.

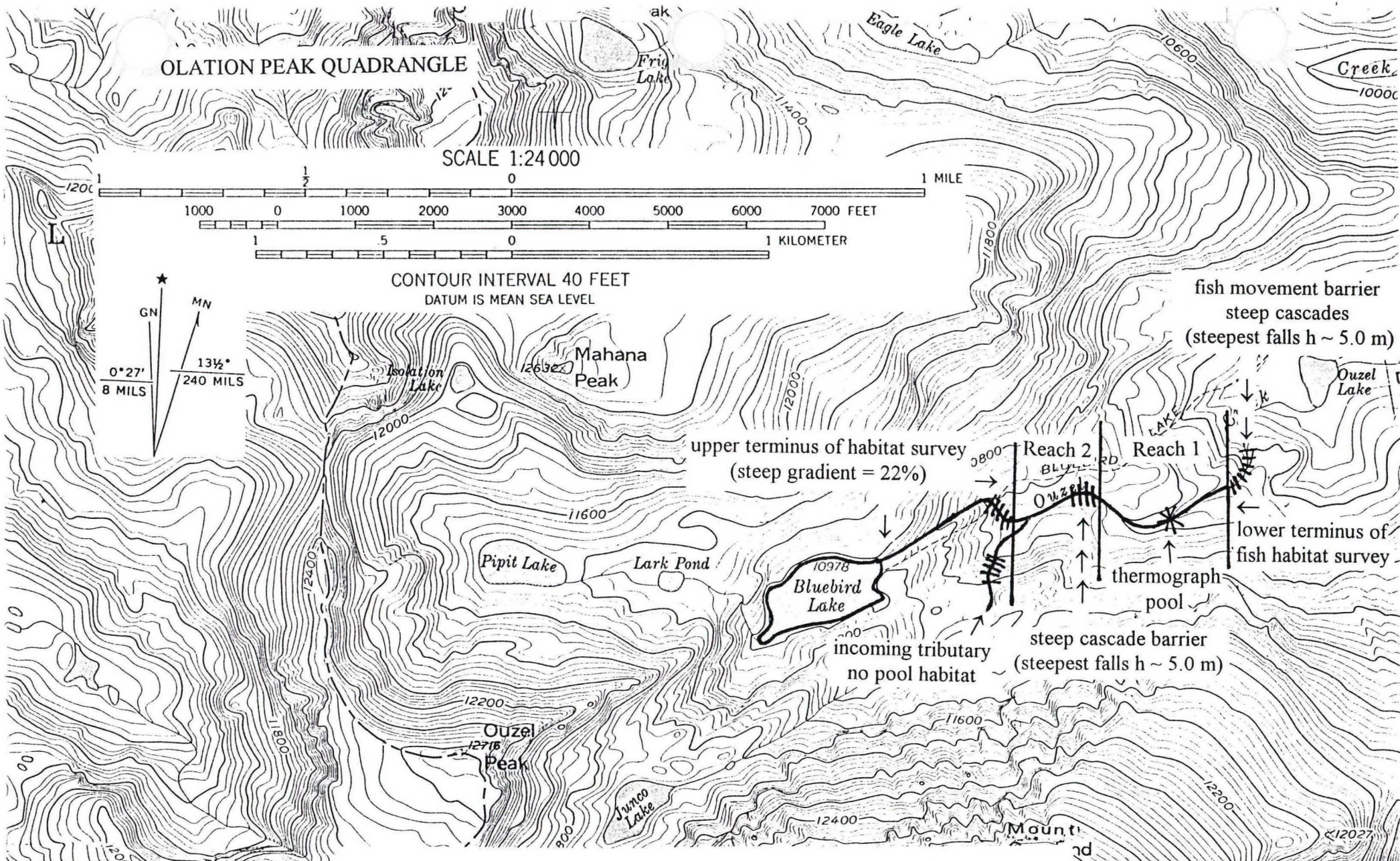

Figure 7. Reach locations for upper Ouzel Creek habitat survey, 11 August 1997.

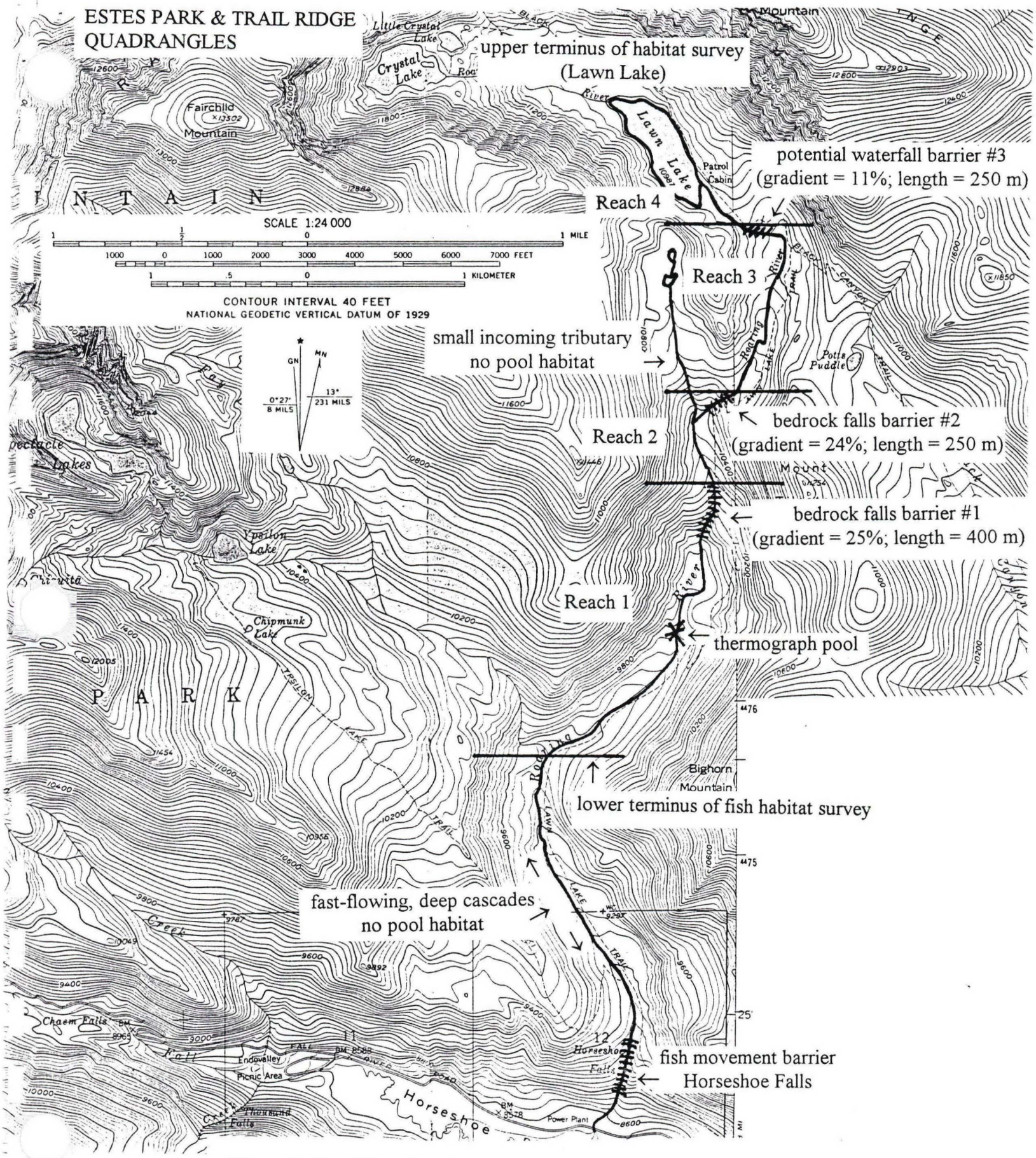

Figure 8. Reach locations for Roaring River habitat survey, 4-6 August 1997.

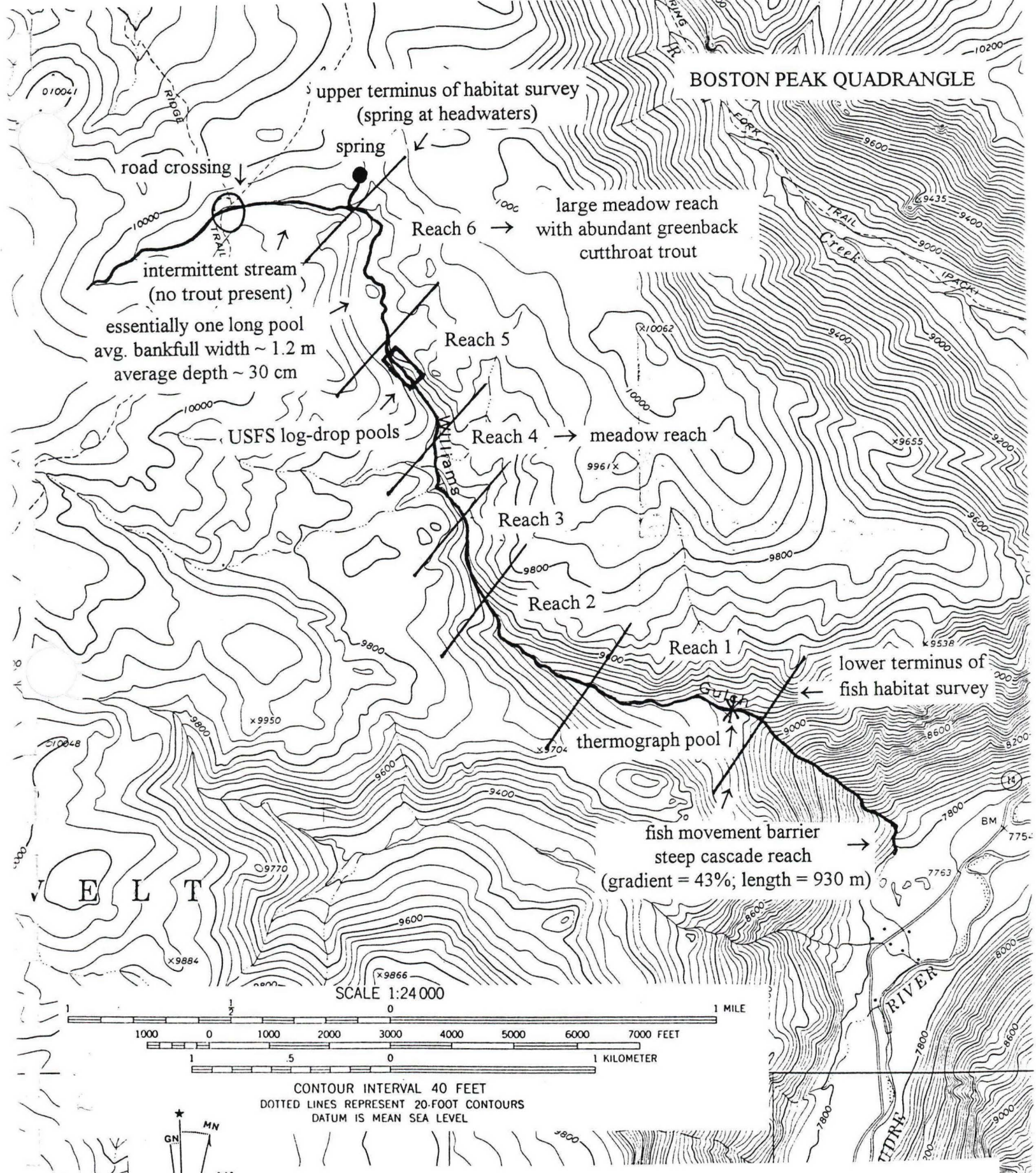

Figure 9. Reach locations for Williams Gulch habitat survey, 25 July and 7 August 1997.

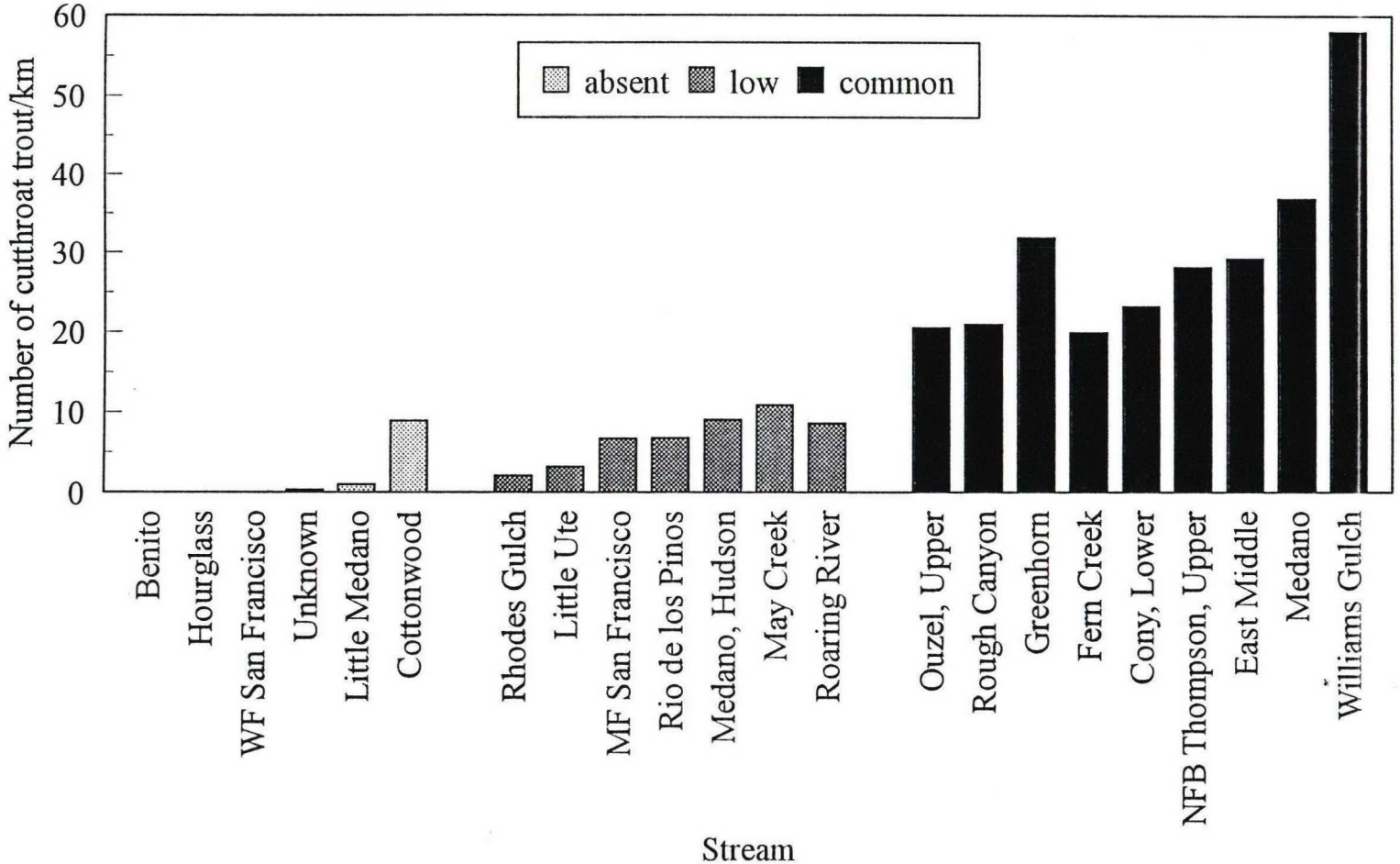

Figure 10. Index of relative trout abundance was determined as the number of cutthroat trout observed in all pools divided by the length of stream surveyed. Data are from 22 randomly selected Rio Grande and greenback cutthroat trout streams surveyed in summers 1996 and 1997. Population status was assigned based on this index, presence of natural reproduction, and previous designation by the Colorado Division of Wildlife. A status rating of "absent" indicates that either no cutthroat trout or no evidence of natural reproduction (i.e., Cottonwood Creek) were present, "low" indicates that the population has some natural reproduction but numbers of trout observed were relatively low, and "common" indicates natural reproduction and greater numbers of cutthroat trout.

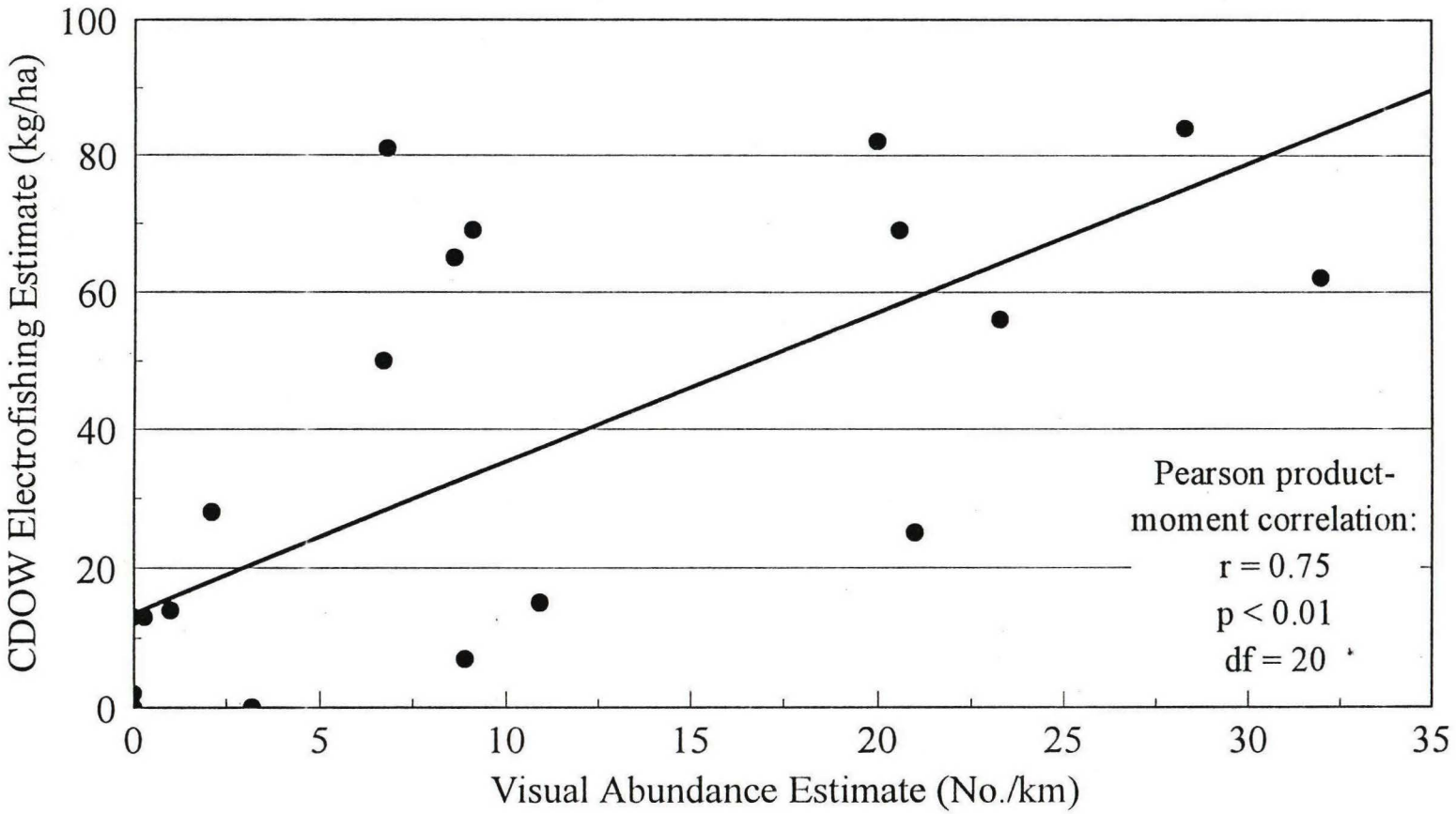

Figure 11. Comparison of cutthroat trout abundance estimates from visual counts during habitat surveys and the Colorado Division of Wildlife's estimates of standing stock based on electrofishing. The visual abundance estimates do not consistently over- or underestimate values from electrofishing data and much of the variation may be attributed to differences in sample length. The visual sample includes the entire stream whereas estimates based on electrofishing utilize shorter reaches that are not likely to be representative of all habitat.

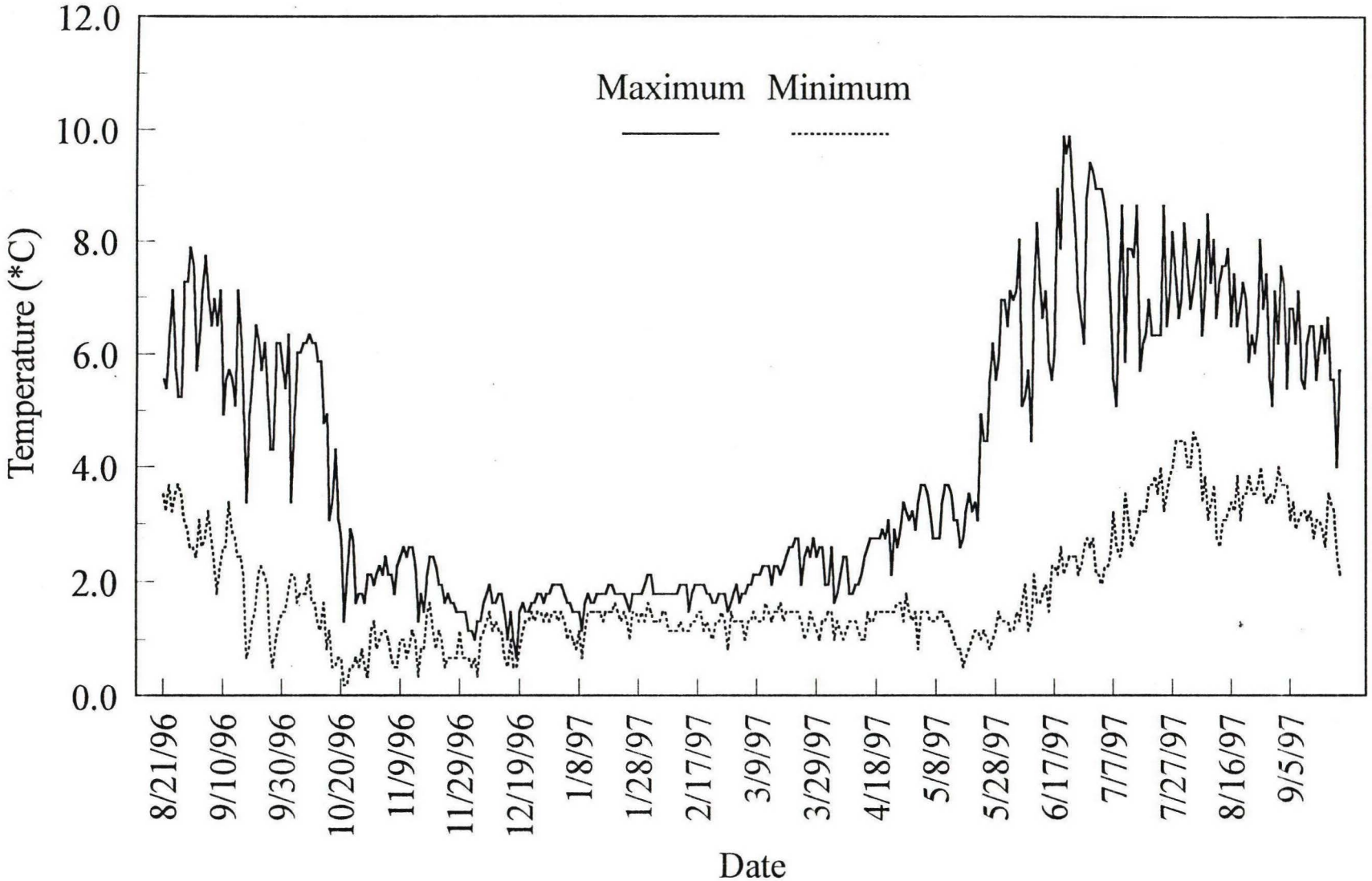

Figure 12. Maximum and minimum daily temperatures in Benito Creek, 8/21/96 - 9/22/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

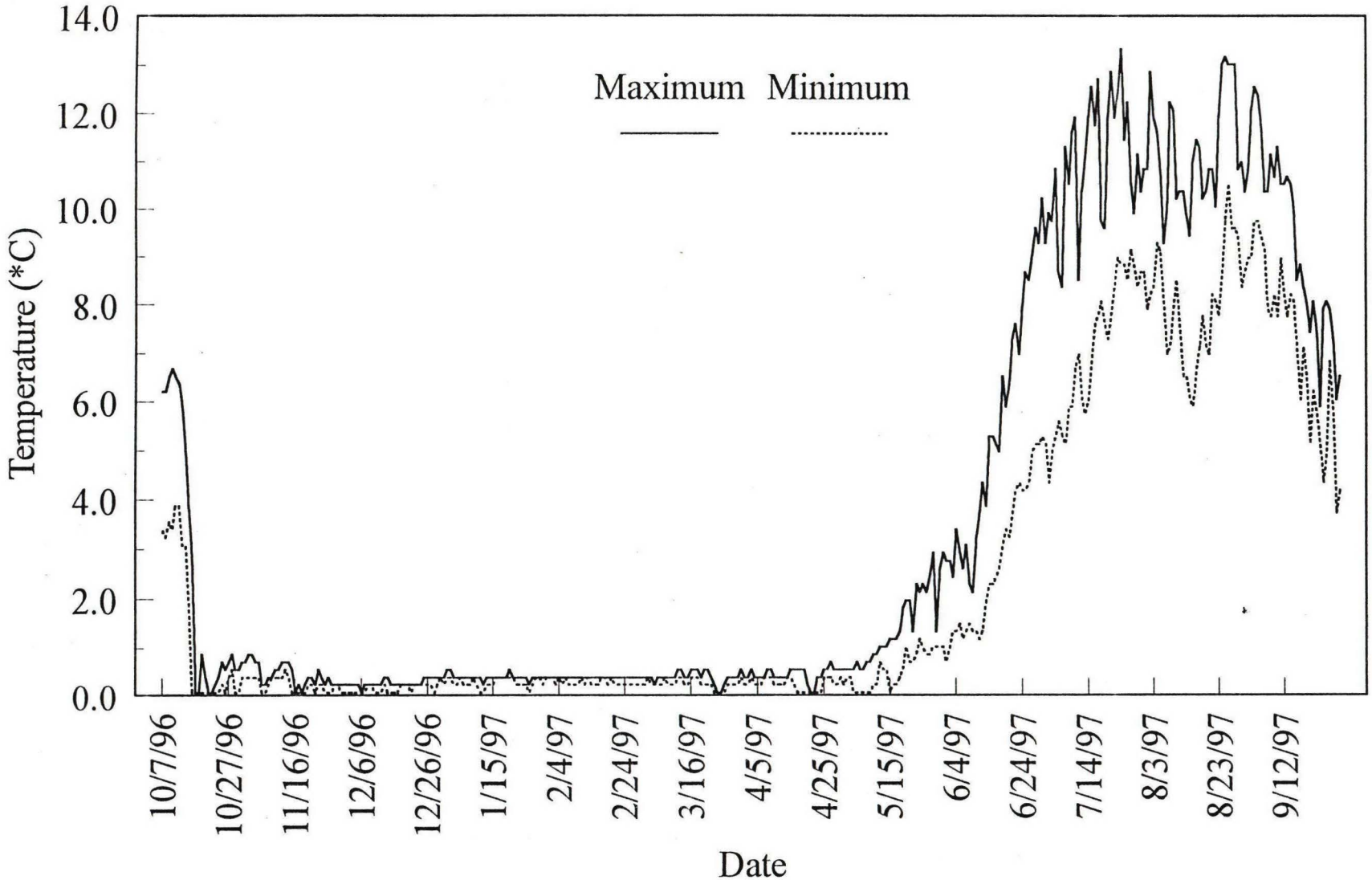

Figure 13. Maximum and minimum daily temperatures in Lower Cony Creek, 10/7/96 - 9/29/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

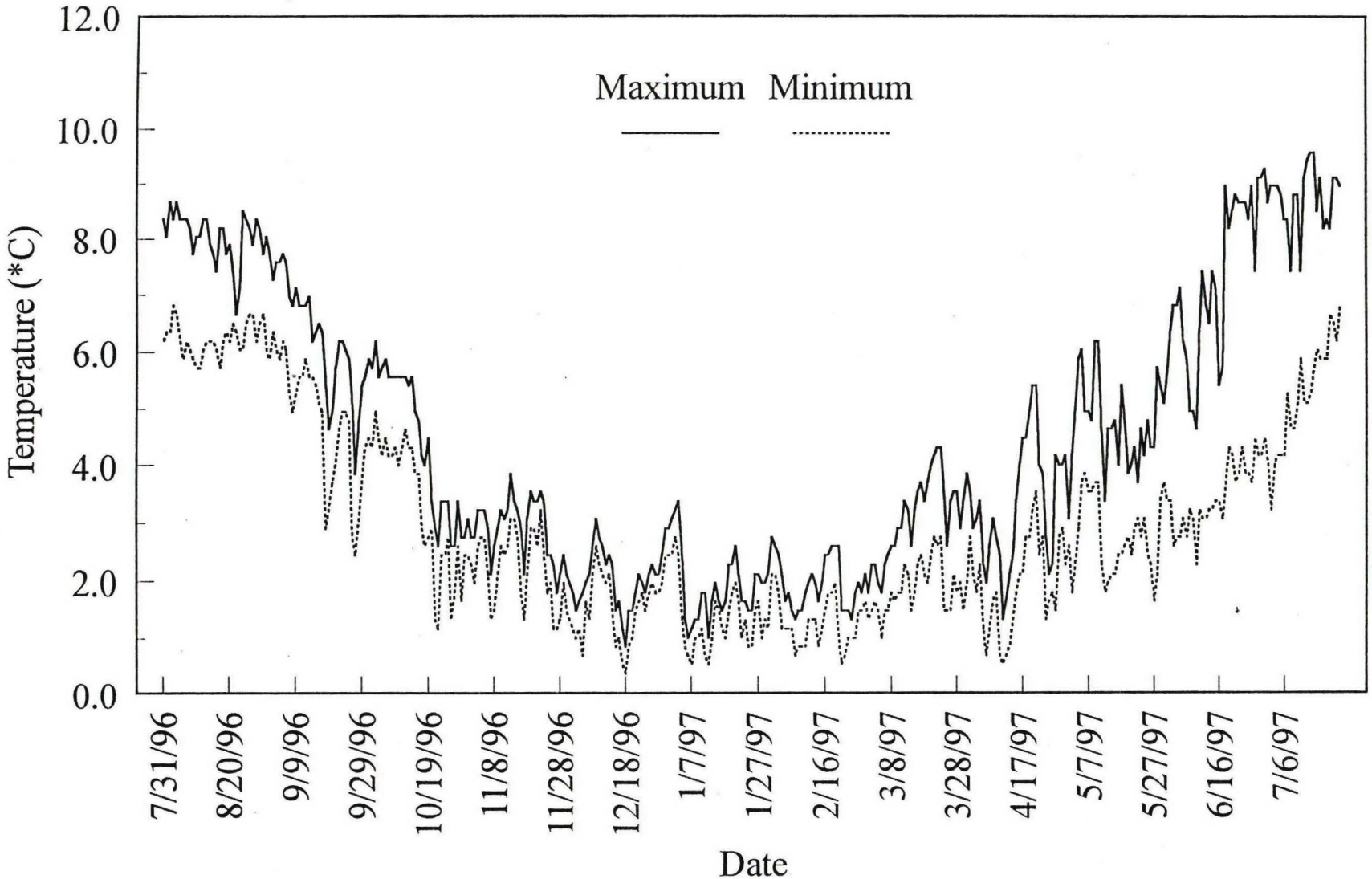

Figure 14. Maximum and minimum daily temperatures in Cottonwood Creek, 7/31/96 - 7/23/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

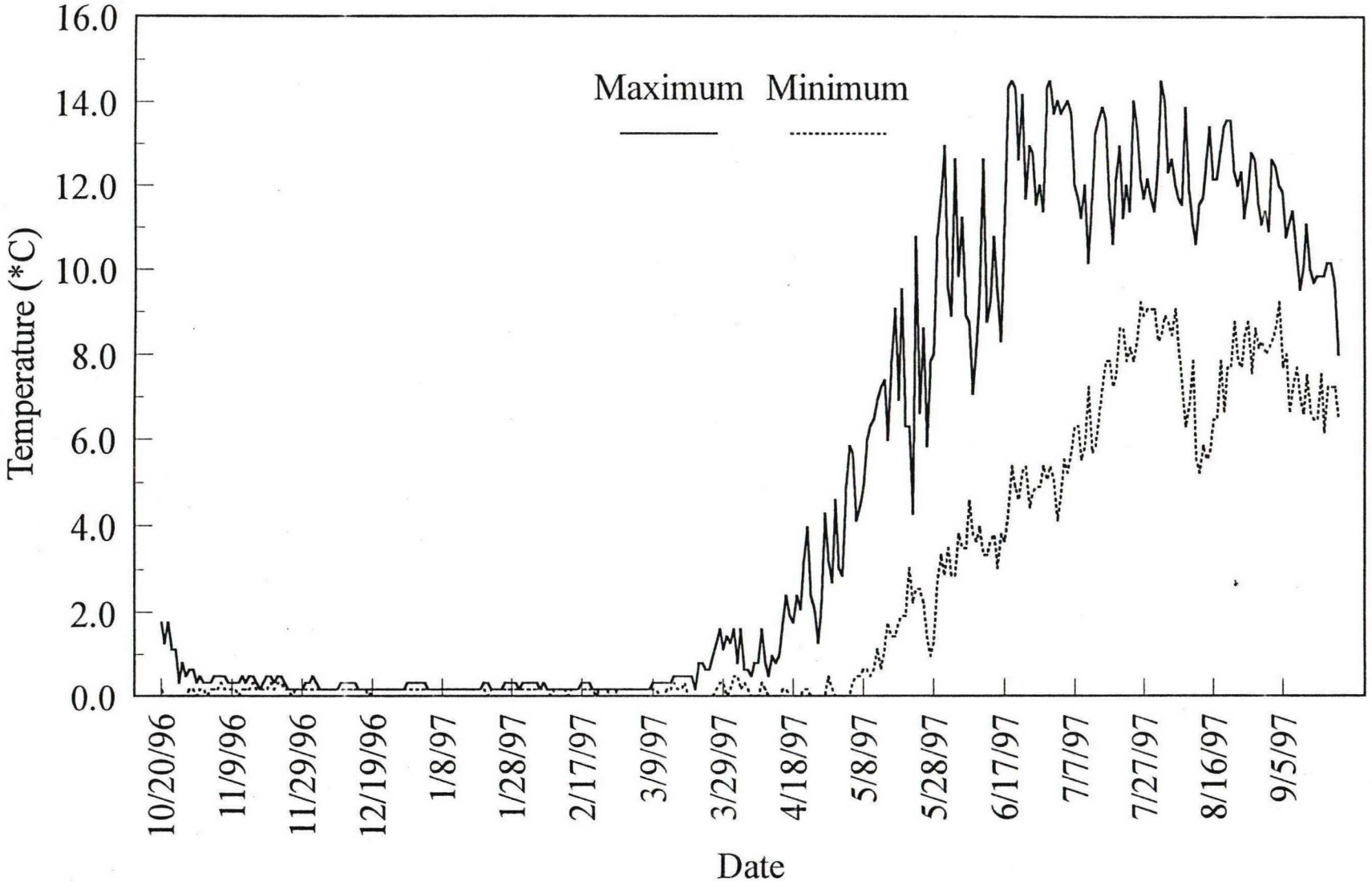

Figure 15. Maximum and minimum daily temperatures in East Middle Creek, 10/20/96 - 9/21/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

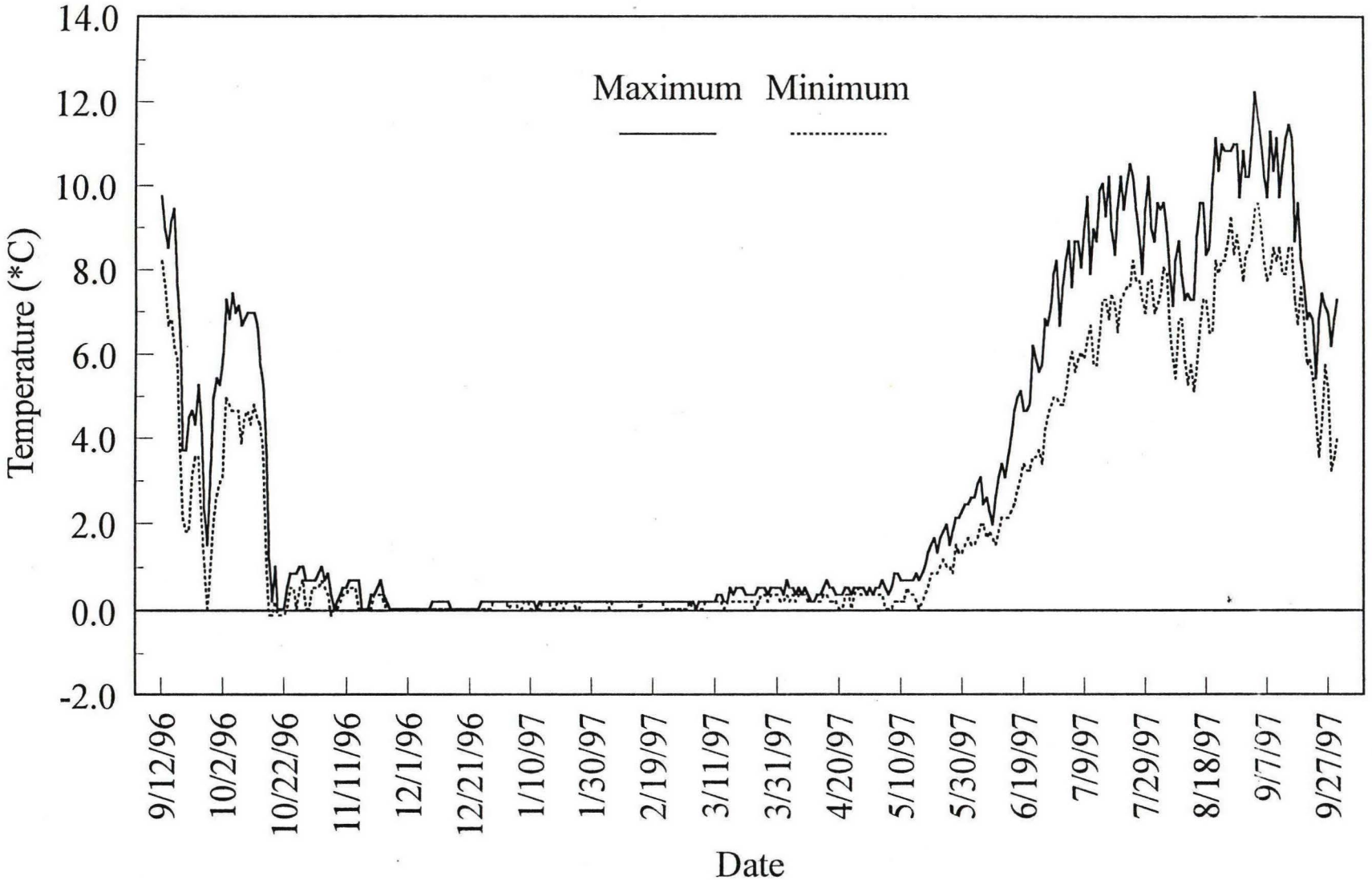

Figure 16. Maximum and minimum daily temperatures in Fern Creek, 9/12/96 - 9/30/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

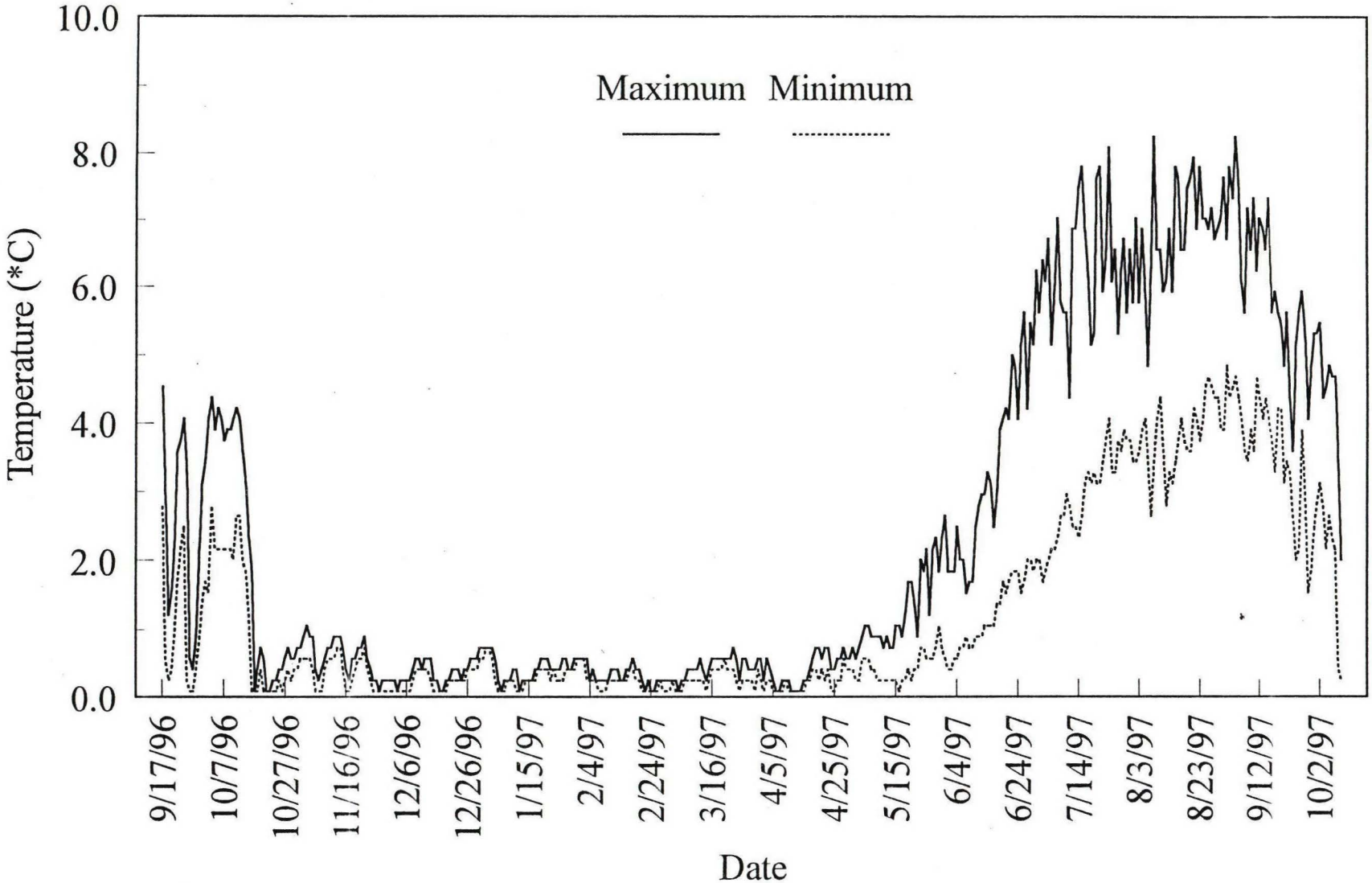

Figure 17. Maximum and minimum daily temperatures in Hourglass Creek, 9/17/96 - 10/9/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

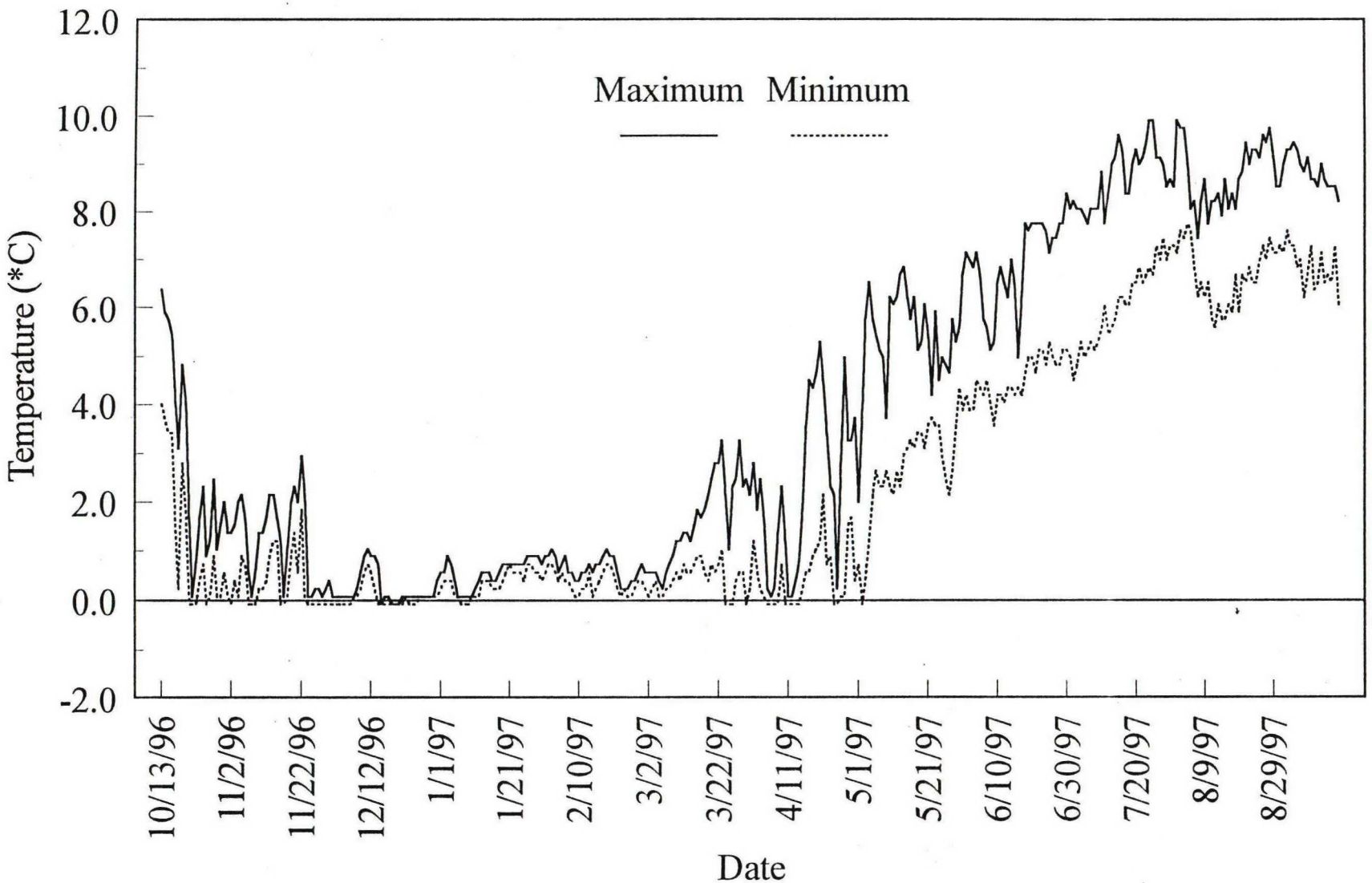

Figure 18. Maximum and minimum daily temperatures in Little Medano Creek, 10/13/96 - 9/17/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

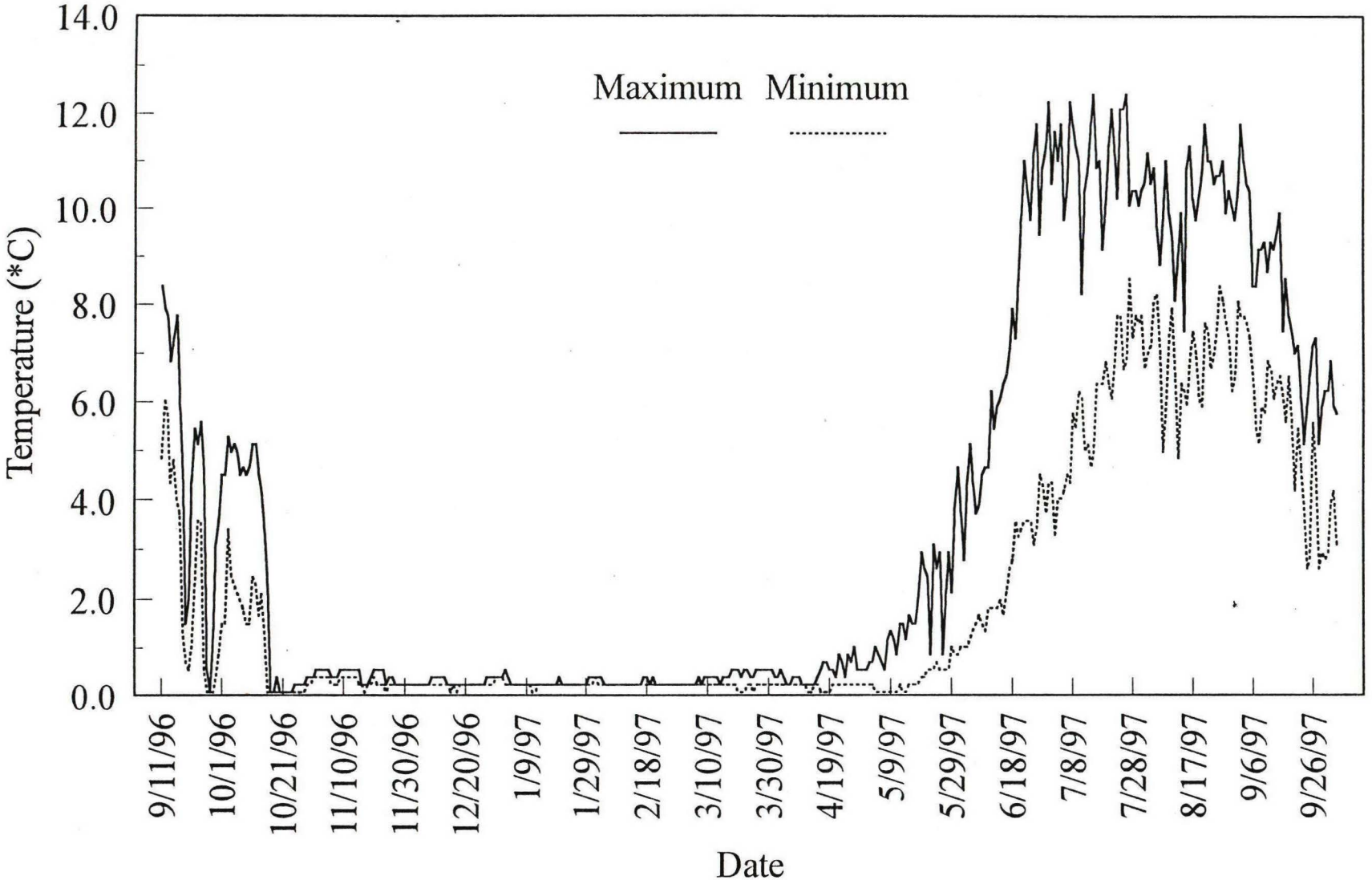

Figure 19. Maximum and minimum daily temperatures in May Creek, 9/11/96 - 10/4/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

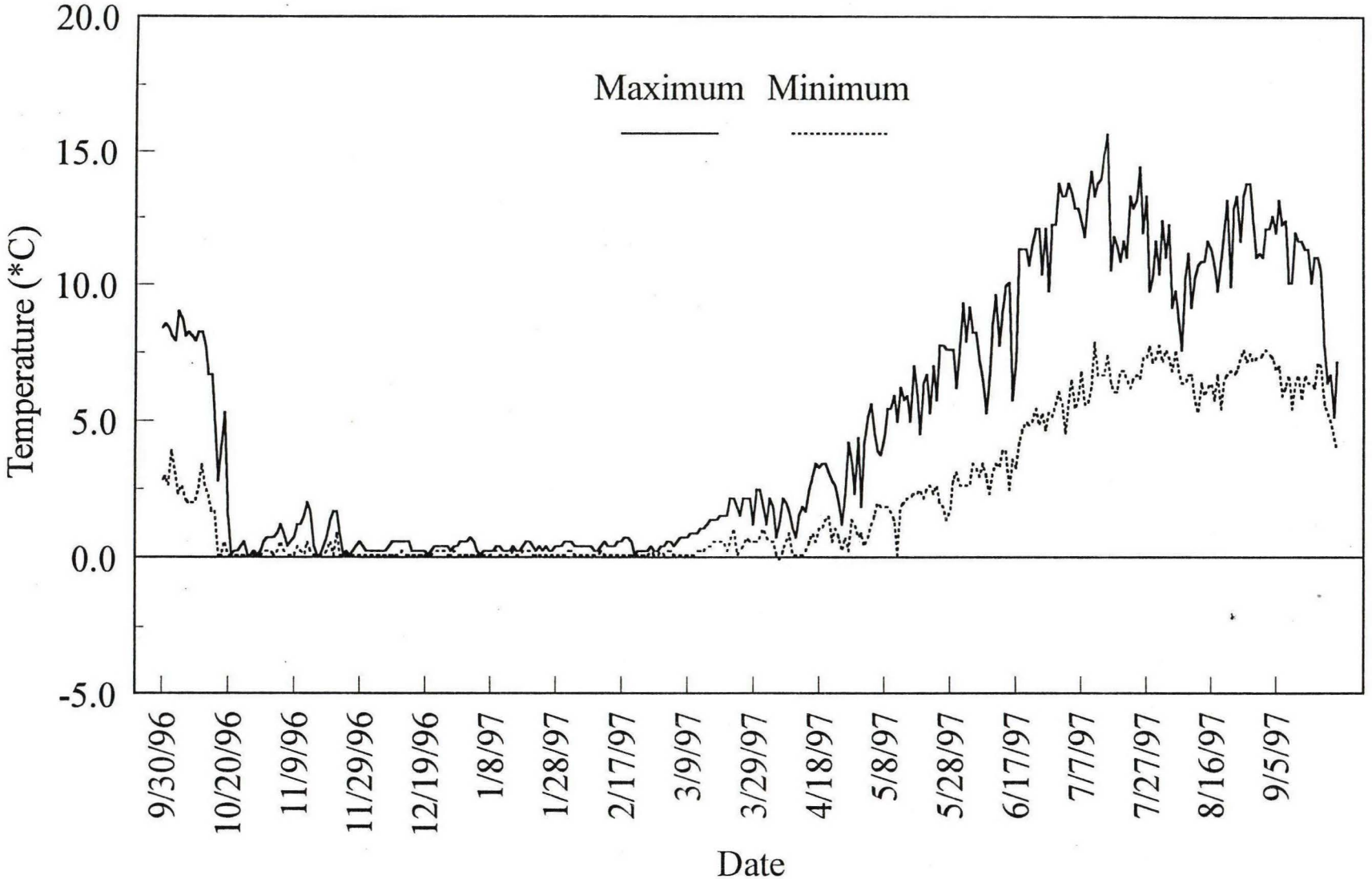

Figure 20. Maximum and minimum daily temperatures in Medano Creek, Hudson Branch, 9/30/96 - 9/24/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

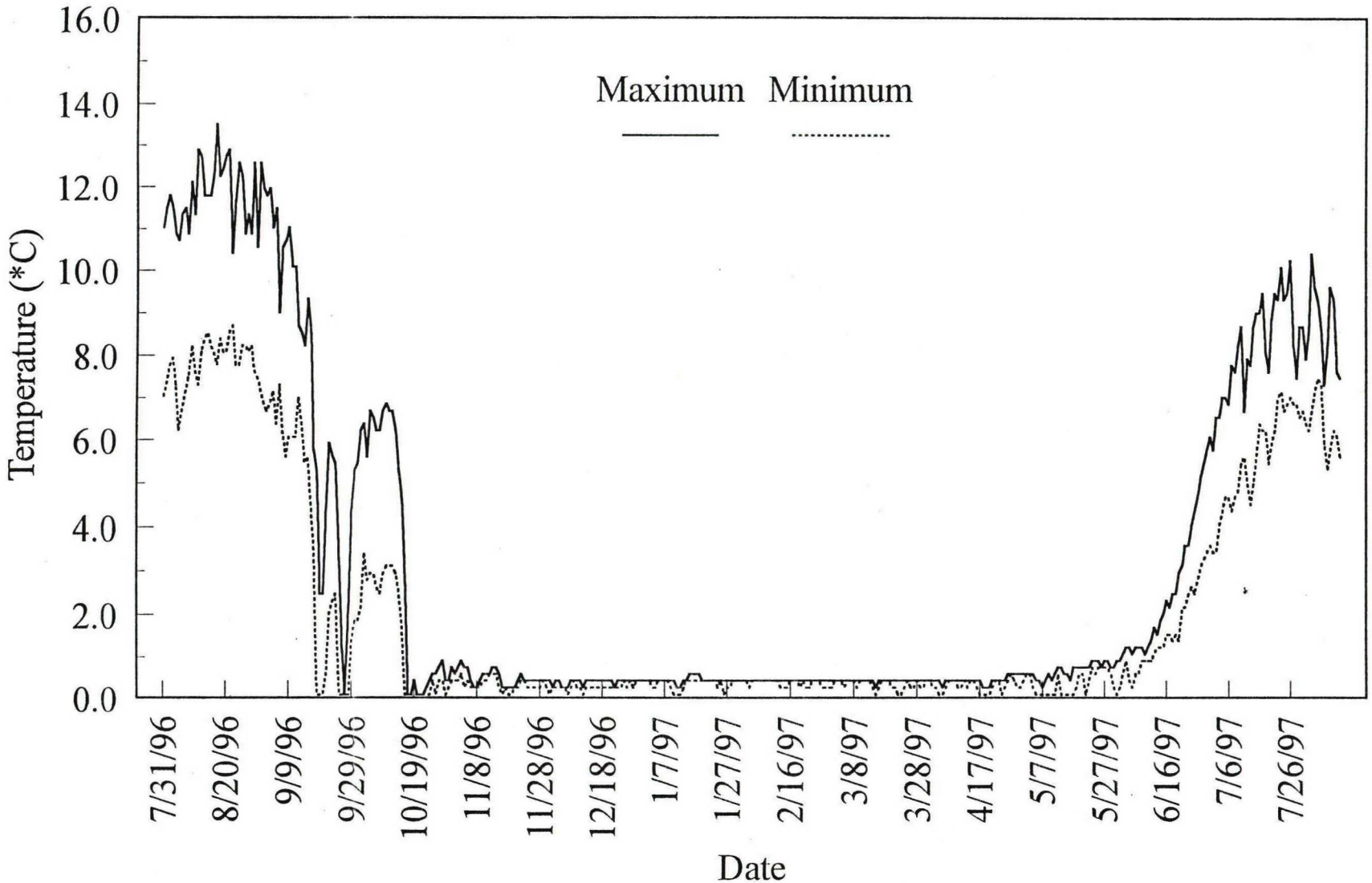

Figure 21. Maximum and minimum daily temperatures in upper Ouzel Creek, 9/30/96 - 8/11/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

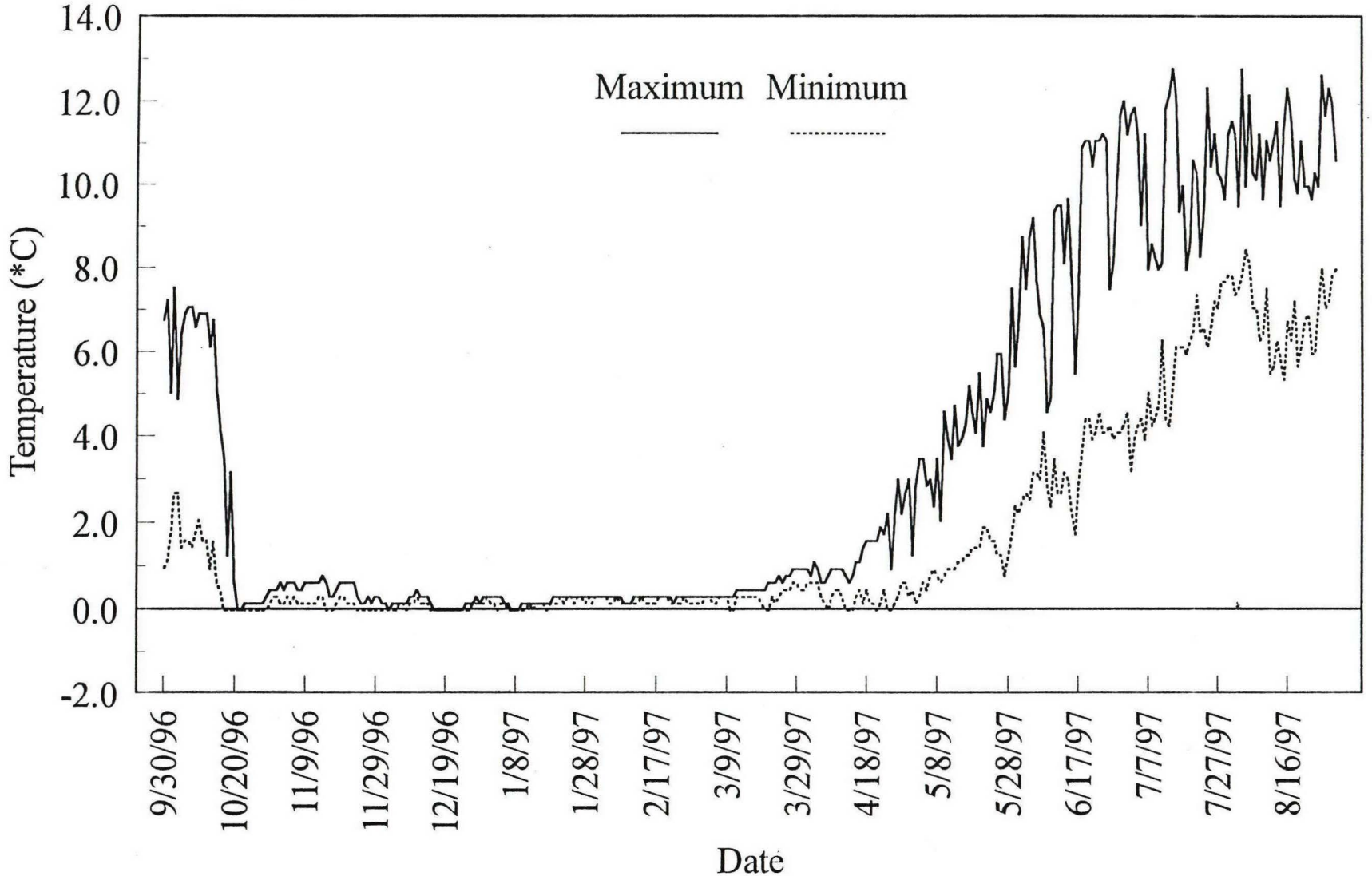

Figure 22. Maximum and minimum daily temperatures in Rhodes Gulch, 9/30/96 - 8/30/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

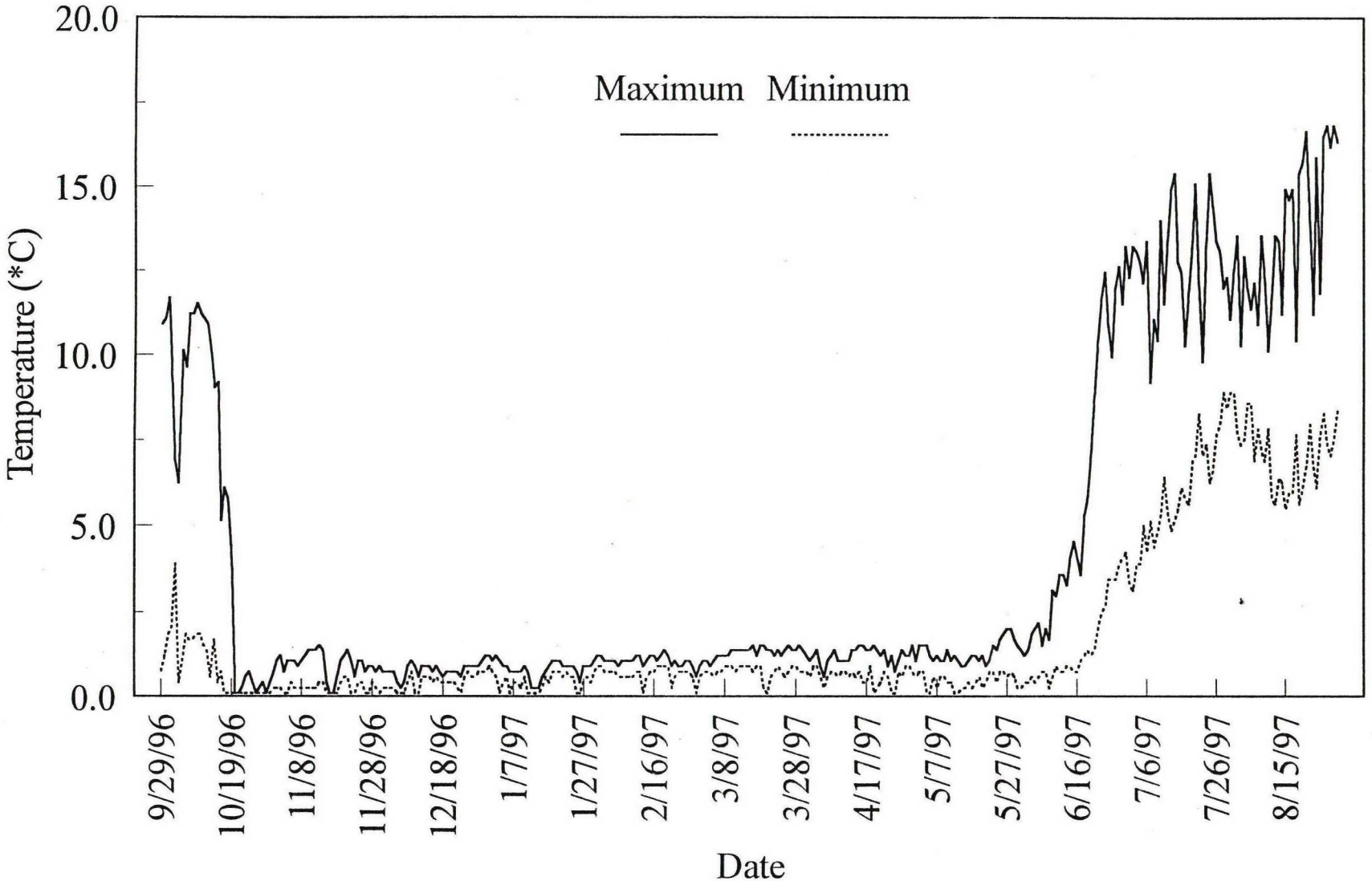

Figure 23. Maximum and minimum daily temperatures in Rio de los Pinos, 9/29/96 - 8/30/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

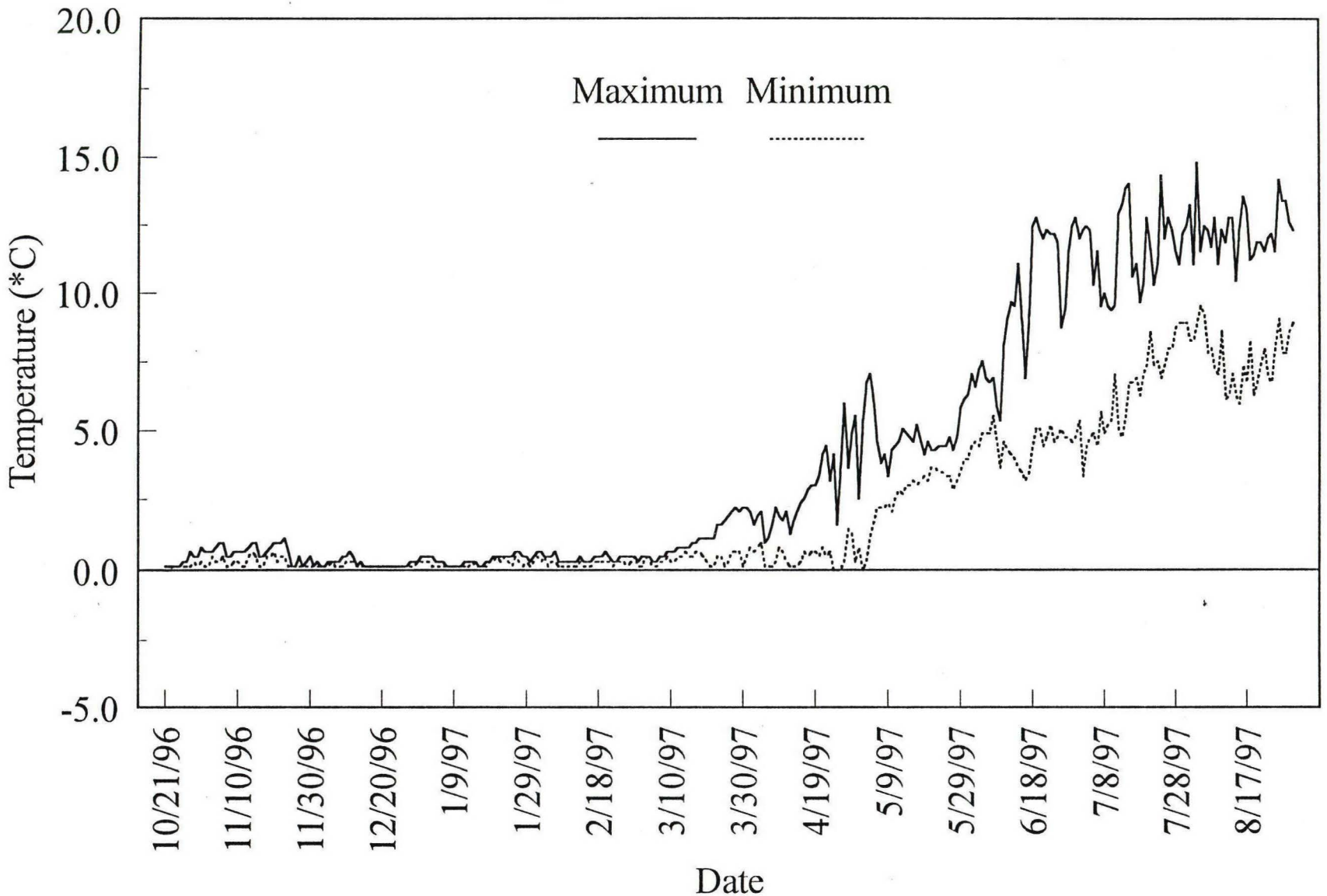

Figure 24. Maximum and minimum daily temperatures in Rough Canyon, 10/21/96 - 8/30/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

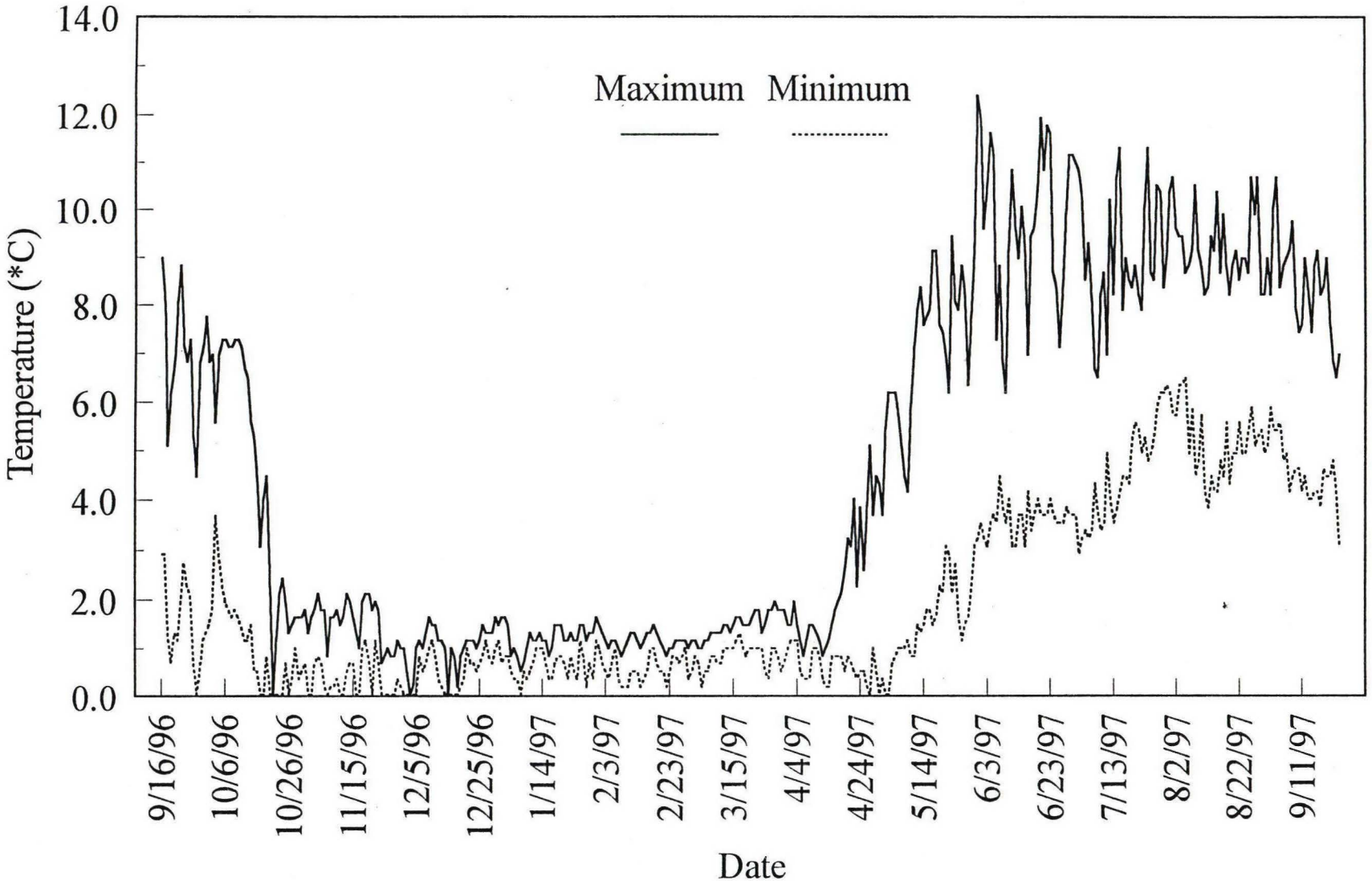

Figure 25. Maximum and minimum daily temperatures in Unknown Creek, 9/16/96 - 9/23/97, measured with an Onset Optic Stowaway thermograph placed in the largest pool.

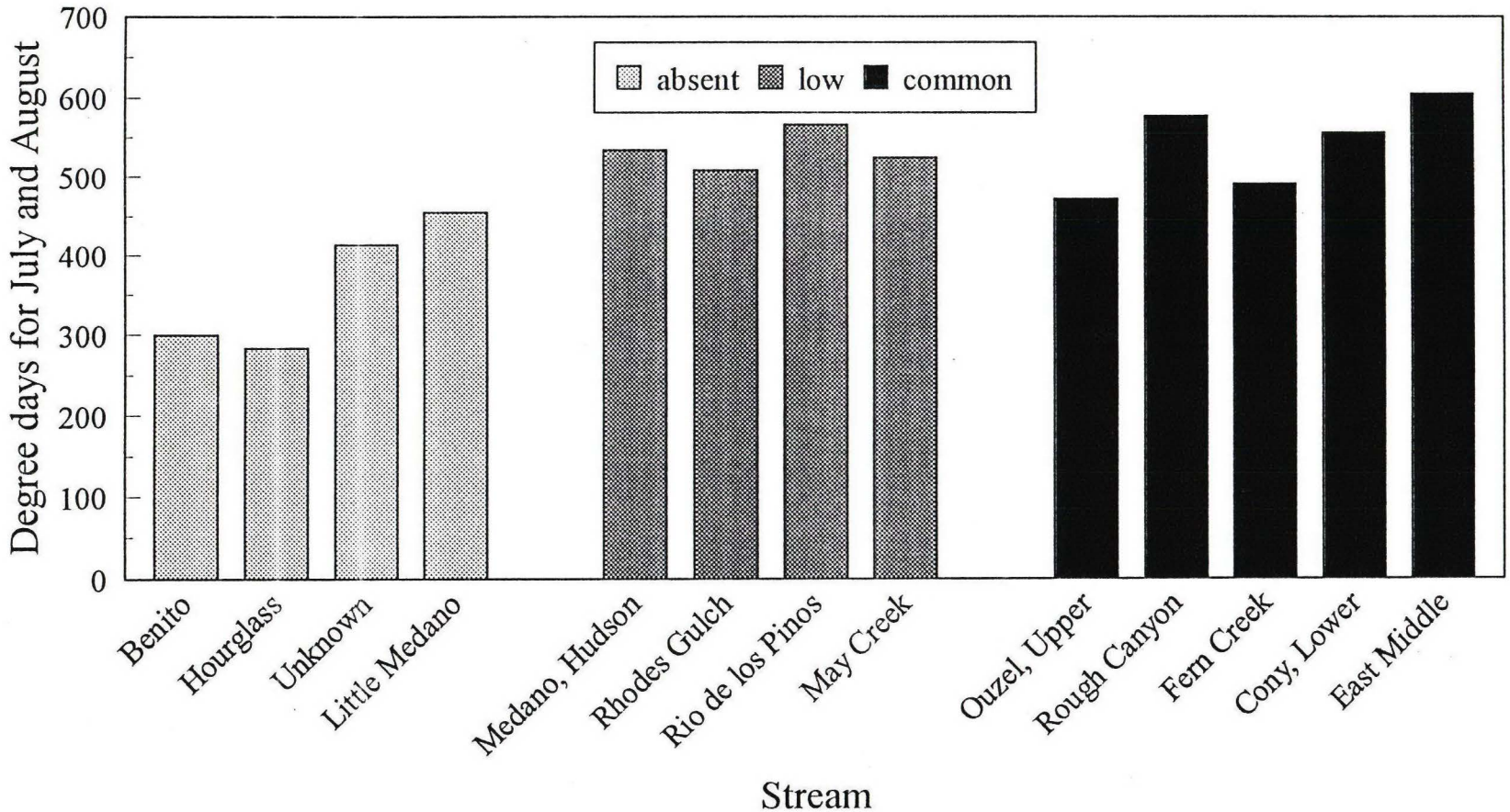

Figure 26. The sum of mean daily temperatures (Celsius degree days) for July and August, months which roughly approximate dates for incubation of eggs and emergence of cutthroat trout fry, ranged from 284 DD in Hourglass Creek to 605 DD in East Middle Creek. Data for Cottonwood Creek were only available up to 7/23/97, so could not be included in the analyses at this time. Streams with populations classified as absent had significantly lower temperatures than streams classified as low or common ($p=0.0004$ by ANOVA), strongly suggesting that low summer temperatures may be a limiting habitat factor for cutthroat trout populations.

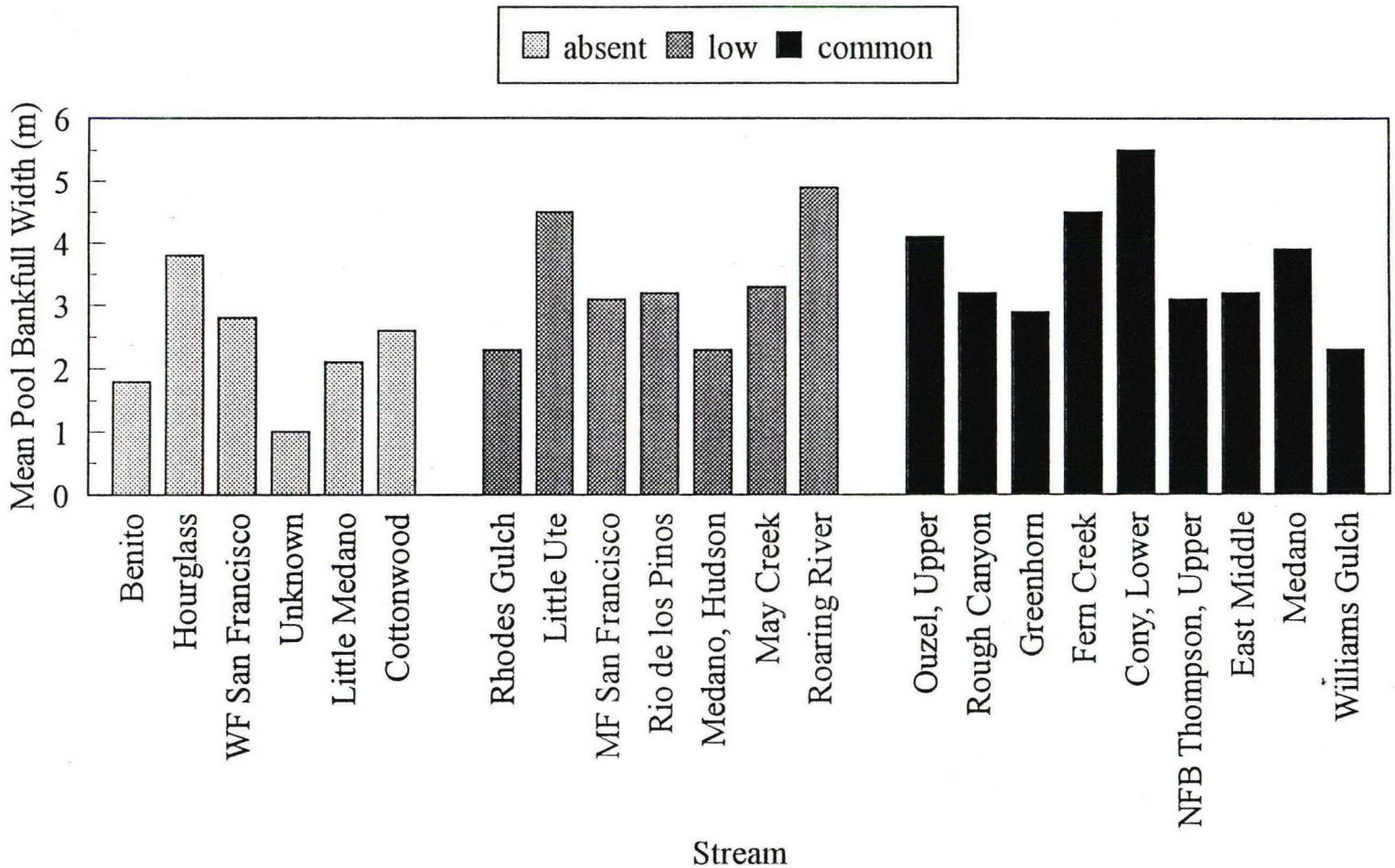

Figure 27. The best preliminary logistic regression model incorporating field habitat data from 22 streams included average bankfull width of pools as a factor predicting the presence (low and common status categories combined) versus absence of cutthroat trout. Bankfull width is positively associated with presence of cutthroat trout ($p = 0.02$ by ANOVA).

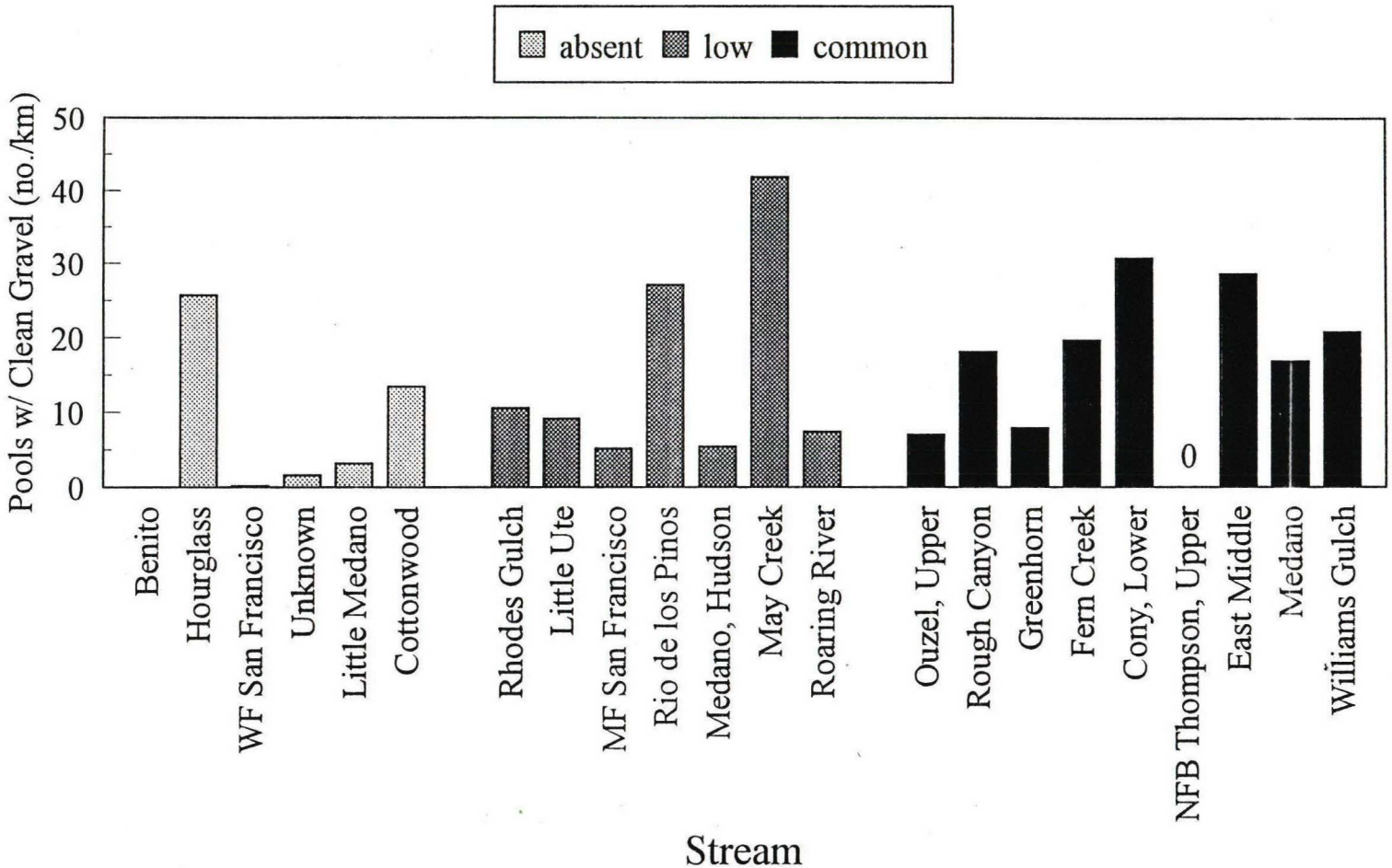

Figure 28. The best preliminary logistic regression model incorporating field habitat data from 22 streams included density of pools with clean gravel as a factor predicting the presence (low and common status categories combined) versus absence of cutthroat trout. Density of pools with clean gravel is positively associated with presence of cutthroat trout ($p = 0.12$ by ANOVA).

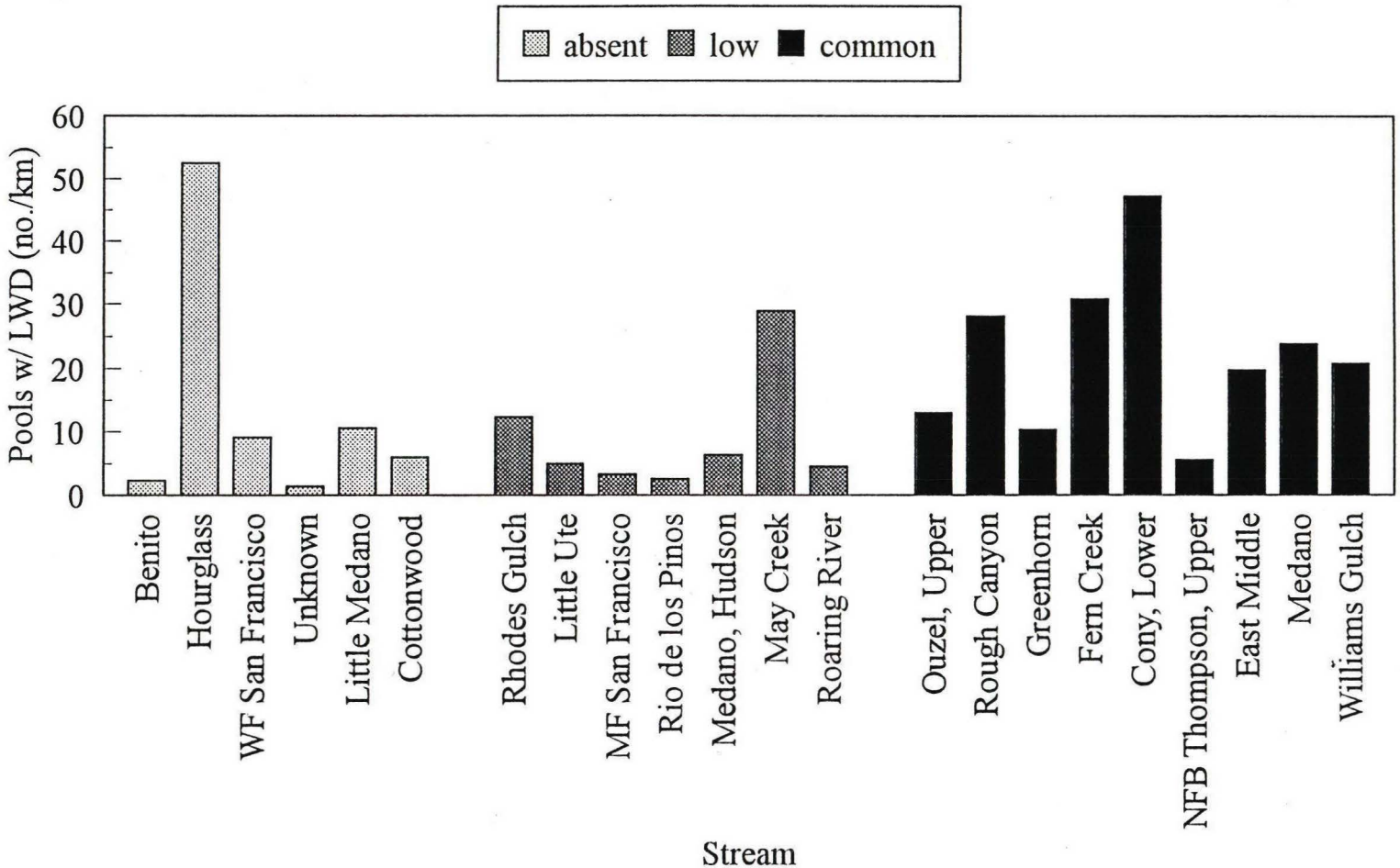

Figure 29. The best preliminary logistic regression model incorporating field habitat data from 22 streams included density of pools with large woody debris as a factor predicting the presence (low and common status categories combined) versus absence of cutthroat trout. Density of pools with large woody debris is inversely related to presence of cutthroat trout if Hourglass Creek is included ($p = 0.70$ by ANOVA), but positively associated with presence of cutthroat trout if Hourglass Creek is excluded as an outlier ($p=0.09$ by ANOVA).